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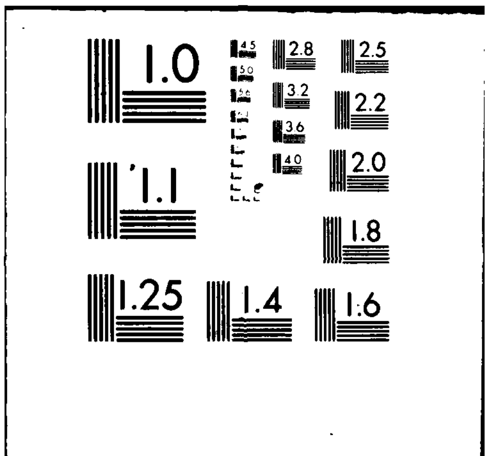

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A STUDY OF EMBEDDED COMPUTER SYSTEMS SUPPORT

VOLUME VII

REQUIREMENTS BASELINE: OPERATIONAL FLIGHT PROGRAMS

September 1980

APPROVED FOR PUBLIC RELEASE
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CDRL 02A
Contract Number F33600-79-C-0540

Prepared for
Air Force Logistics Command AFLC/LOEC
Wright Patterson AFB, Ohio 45433

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This portion of the study focuses on Operational Flight Programs (OFP'S) pertaining to avionics functions. Specifically it relates (to the following generic avionics functions; navigation, controls and displays, rapar, weapon control/delivery. Flight control, flight recording, engines, and built-in-test. The weapon systems/ subsystems and the primary function controlled by their respective OFP'S are shown and evallated. (See related volumes: LD 47169A,

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FOREWORD

This volume is one of nine individually bound volumes that constitute the Phase II Final Report "Study of Embedded Computer Systems Support" for Contract F33600-79-C-0540. The efforts and analyses reported in these volumes were sponsored by AFLC/LOEC and cover a reporting period from September 1979 through September 1980.

The nine volumes are

Volume	Title
I	Executive Overview (CDRL 05)
II	Selected ECS Support Issues: Recommendations/ Alternatives (CDRL 02A)
III	Requirements Baseline: Aircrew Training Devices (CDRL 02A)
IV	Requirements Baseline: Automatic Test Equipment (CDRL 02A)
V	Requirements Baseline: Communications-Electronics (CDRL 02A)
VI	Requirements Baseline: Electronic Warfare (CDRL 02A)
VII	Requirements Baseline: Operational Flight Programs (CDRL 02A)
VIII	ECS Technology Forecast (CDRL 03)
IX	National Software Works Investigation (CDRL 04)

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CONTENTS (continued)

CONTENTS (Concluded)

TABLES

ILLUSTRATIONS

ABBREVIATIONS AND ACRONYMS

ACM	Air Combat Maneuvering
ADI	Attitude Direction Indicator
AEB	Avionics Equipment Bay
AFCS	Automatic Flight Control System
AIS	Avionics Intermediate Shop
ATE	Automatic Test Equipment
BDHI	Bearing Distance Heading Indicator
BMU	Bus Monitor Unit
CADC	Central Air Data Computer
CCB	Configuration Control Board
CCIV	Command Code Inserter Verifier
CCM	Counter Countermeasures
CDR	Critical Design Review
CIV	Code Inserter Verifier
CPCI	Computer Program Configuration Item
CPCP	Computer Program Change Proposal
CPCSB	Computer Program Configuration Sub-Board
CRISP	Computer Resources Integrated Support Plan
DDR	Digital Data Recorder
DPU	Data Processing Unit
DSA	Dynamic Simulation Area
DSS	Dynamic Simulation System
DSSC	Dynamic Simulation System Complex
DTC	Dynamic Test Console

ABBREVIATIONS AND ACRONYMS (Continued)

ECP	Engineering Change Proposal
ECS	Embedded Computer System
ENG	Engineering
EPP	Execution Plan Program
ESS	Electrical Standards Set
EW	Electronic Warfare
FCC	Fire Control Computer
FLR	Forward Looking Radar
FLT	Flight
GNC	General Navigation Computer
GPCC	General Purpose Computer Complex
HETF	Hill Engineering Test Facility
HSD	Horizontal Situation Display
HSI	Horizontal Situation Indicator
HUD	Head Up Display
ID	Identification
IM	Item Manager
IMU	Inertial Measurement Unit
INS	Inertial Navigation Set
ITB	Integration Test Bed
ITE	Integration Test Equipment
IV&V	Independent Verification and Validation

ABBREVIATIONS AND ACRONYMS (Continued)

LCF	Launch Control Facility
LCOSS	Lead Computing Optical Sight System
LF	Launch Facility
LRU	Line Replaceable Unit
MOTP	Minuteman Operational Targeting Program
MSRD	Master Software Requirements Document
NCU	Navigation Computer Unit
OEP	Operational Executive Program
OFP	Operational Flight Program
OGP	Operational Ground Program
O/SCMP	Operational/Support Configuration Management Procedure
OT&E	Operational Test and Evaluation
PDR	Preliminary Design Review
PMRT	Program Management Responsibility Transfer
REO	Radar Electrical Optical
RES	Radar Engineering Stand
SIM	Simulation
SM	System Manager
SMS	Stores Management System
SMSB	Strategic Missile Support Base
SRR	System Requirements Review
STB	Software Test Bed
STS	Static Test Stand
STSS	SAC Targeting Support Software

ABBREVIATIONS AND ACRONYMS (Concluded)

TCG	Target Constants Generation Program
TISEO	Target Identification System Electro-Optical
TRC	Technology Repair Center
V&V	Verification and Validation
WDC	Weapon Delivery Computer
WSC	Weapon System Controller

1. OPERATIONAL FLIGHT PROGRAMS

1.1 BACKGROUND

Airborne weapon systems are traditionally partitioned into airframe, propulsion, and avionics with avionics generally defined as including all electronics on board the air vehicle. Also in a historical sense, avionic suites evolved by the addition of a new "black box" for each new capability or function with the aircrew serving as the primary integrator of the often simultaneous perishable data.

The introduction of computer resources (computers and computer programs) provided not only the potential for greatly improving weapon system capability, flexibility, and performance but the capability to integrate the avionics functions and reduce aircrew work load to an efficient management level. In time, computer resources in weapon systems became known as embedded computer systems and the airborne computer programs that integrated avionic functions became known as Operational Flight Programs (OFP). The OFP is further defined as that software/firmware which executes in the embedded computer(s) or subsystem(s) within an avionic suite and performs functions that are integral to the on board system. In essence the OFP is the integrator and controller for the avionic system/subsystem/item.

1.2 WEAPON SYSTEMS CONTAINING EMBEDDED COMPUTER SYSTEMS

A computer using digital techniques was first applied to the MA-1 fire control system of the F-106 in the late 1950's. The F/FB-111 were the first major aircraft systems to use integrated digital avionics. Since that time embedded computer systems have been used in varying degrees in several aircraft avionics systems and are used extensively in most new aircraft and missile systems. Major missile systems such as Minuteman II and III incorporate embedded computer systems in both

operational flight and ground based programs. Future ICBM and cruise missile systems are expected to continue this practice. Those weapon systems/subsystems currently containing ECS with operational flight programs are shown in Table 1-1. This list is not intended to be exhaustive of systems bearing the label OFP but does include those systems of importance to the OFP ECS category baseline.

1.3 FUNCTIONS PERFORMED BY OPERATIONAL FLIGHT PROGRAMS

The primary functional requirements of a typical USAF avionics system/subsystem subject to OFP integration or control are extensive. Table 1-2 shows representative avionics functions grouped according to system, sensor, and mission functions. Controls and displays is an additional function which cuts across the other functions particularly in the area of display symbology.

Currently aircraft OFP's resident in embedded computers primarily integrate/control the following generic avionics functions:

- Navigation
- Controls and displays
- Radar
- Weapon control/delivery
- Flight control
- Flight recording
- Engines
- Built-in-test

Table 1-3 shows the weapon systems/subsystems and the primary function controlled by their respective OFP's. Also shown is the number of OFP related embedded computers in the ECS.

Table 1-1. Weapon Systems Containing OFP's

Weapon System	Primary Role/Mission	Principle Operating Command	Operational Status	Principle OFP Supporting Command/Center
A-7D	Fighter Bomber	TAC	Transitioned	OC-ALC
AC-130A	Interdiction	TAC	Transitioned	OC-ALC
AC-130H	Interdiction	TAC	Transitioned	OC-ALC
C-130	AWADS	MAC	Transitioned	OC-ALC
C-5A	Cargo/Transport	MAC	Transitioned	SA-ALC
KC/C-135	Cargo/Transport	SAC	Transitioned	OC-ALC
C-141A	Cargo/Transport	MAC	Transitioned	OC-ALC
DC-130E	Drone Launch	TAC	Transitioned	OC-ALC
E-3A	Warning/Control	TAC	Transitioned	OC-ALC
E-4	Command/Control	SAC	Acquisition	OC-ALC
EC-135J	Surveillance	PACAF	Transitioned	OC-ALC
F-4E	Fighter Bomber	TAC	Transitioned	OO-ALC
F-4G	Defense Suppression	TAC	Acquisition	OO-ALC
F-15A	Air Superiority	TAC	Requisition	WR-ALC
F-16A	Air Superiority	TAC	Acquisition	OO-ALC
F-106A	Air Defense	ADCOM	Transitioned	SA-ALC
F-111D/F	Fighter Bomber	TAC	Transitioned	SM-ALC
FB-111A	Strategic Bomber	SAC	Transitioned	SM-ALC
HH-53C	Classified	PACAF	Transitioned	OC-ALC
RC-135	Reconnaissance	SAC	Transitioned	OC-ALC
RF-4C	Reconnaissance	TAC	Transitioned	OO-ALC
T-43A	Training	ATC	Transitioned	SA-ALC
Minuteman II/III	ICBM	SAC	Transitioned	OO-ALC
AN/AVQ-26	Target Acquisition	TAC	Acquisition	WR-ALC
AGM-69A	Defense Suppression	SAC	Transitioned	OC-ALC

Table 1-2. Representative Avionic Functions

- System functions

  Engine
  Fuel
  Hydraulic
  Electrical
  Lighting
  Flight control
  Communications
  Navigation
  Built-in-test
  Environment control

- Sensor functions

  Air data
  Attitude and heading
  Navigation
  Target/threat
  Data smoothing
  Flight recorder

- Mission functions

  Departure and arrival
  Enroute
  Stores management/weapon delivery
  - Air-to-air
  - Air-to-ground

Note: Electronic warfare systems, although avionic functions, are grouped in a separate category.

Table 1-3. ECS Category OFP Primary Functions

Primary OFP Functions	A-7D	AC-130A	AC-130H	C-130	C-5A	KC/C-135	C-141A	DC-130E	E-3A	E-4	EC-135J	F-4E	F-4G	F-15A	F-16A	F-106A	F-111D/F	FB-111A	HH-53C	RC-135	RF-4C	T-43A	Minuteman	AN/AVQ-26	AGM-69A
Navigation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Controls and Displays	X											X	X	X	X		X	X			X				
Radar												X	X	X	X		X	X			X				
Weapon Control/ Delivery	X		X									X	X	X	X	X	X	X					X	X	
Flight Control												X	X		X						X				
Engines															X										
Flight Recording					X									X							X				
Built-in-Test			X								X	X	X	X	X		X	X	X		X				
Number of OFP Related Computers†	2	1	1	1	3	1	1	1	1	1	1	3	2	4	7	1	3	3	1	1	2	1	6	1	1

† Does not include EW computers.

2. OFP CATEGORY ECS SUPPORT REQUIREMENTS

The support of embedded computer systems which are made up of computer equipment and computer programs is based upon the experience that over a period of time changes/modifications will be necessary to correct deficiencies, enhance system capabilities in response to operational need, and adapt the weapon system to a new role or mission during the period of its life cycle. Experience also shows that system deficiencies and modifications are frequently more readily correctable by altering the software than the hardware.

Support requirements are driven by the nature of the embedded computer system's functional role in the weapon system. For example, if the OFP is resident in an Inertial Measurement Unit (IMU) and navigation is the only ECS function, the support requirement will be of different magnitude than if the OFP is the integrator and controller for a weapon system that delivers nuclear weapons. In either case however, the task of changing or modifying the ECS can be partitioned into a definable set of requirements. These requirements are often thought of as activities or expressed as a sequential process. At a higher level abstraction, the requirement may be viewed simply as keeping the weapon system responsive to operational need.

Operational flight program support requirements in the post-PMRT phase of the life cycle are normally the responsibility of the Air Force Logistics Command and are accomplished at the Air Logistics Centers. The actual support requirements for OFP's are very similar regardless of the source of the support, i.e., government, contractor, or a combination of the two. The following paragraphs discuss the generic and

unique post-PMRT OFP support requirements which involve the administration and management of engineering and technical activities to maintain program control and to effect changes/modifications to OFP embedded computer systems. Table 2-1 summarizes these activities in the change process.

2.1 ECS CHANGE

2.1.1 Receive and Process Requests

The OFP change process is initiated with the receipt of a deficiency report or requirements change request. This is primarily a management or administrative function but procedures must be established to ensure that all requests are recorded and tracked until they are resolved. Technical assistance may be required to ensure that the requests are clearly stated and understood.

2.1.2 Preliminary Analysis and Problem/Deficiency Definition

The change process requires a certain amount of change analysis effort for every change entered into the system. Some filtering must be accomplished to assure that only serious candidate changes involving software problems are considered. The goal is to realize a normal change processing cycle.

2.1.3 Preliminary Resource Allocation and Scheduling

A common practice is to collect all change requests between major updates and process them in one change cycle. This permits coordination and planning for orderly accomplishment of the change cycle. However, provisions must be made for accommodating urgent or emergency changes.

Table 2-1. Post-PMRT OFP Support Requirements

OFP Change Requirement	Remarks
ECS Change	
• Receive and process requests	• Change requests can originate from a number of sources and can range in importance from emergency/urgent to desired or nice to have. Procedures are required to record and track all change requests.
• Preliminary analysis and problem/deficiency definition	• This activity can be accomplished in varying degrees by the requestor and the supporter depending upon the nature of the problem and the knowledge and tools available.
• Preliminary resource allocation and scheduling	• Involves priorities and coordination with user and sources of support depending upon nature and number of changes.
Change Analysis and Specification	
• Feasibility	• Can the change be accomplished? If not, why? If it can, what is the approach to the solution? What are the likely software, hardware, and system impacts?
• Requirements decomposition/definition	• Alternative design approaches are examined and resources requirements are further detailed for selected approach.
• Preliminary design	• Preliminary design and testing approach is established. Technical conferences and Preliminary Design Revies (PDR) are held.
• Detailed design	• Design approach is finalized; specifications, test procedures, and development plans are prepared/updated. Conduct Critical Design Reviews (CDR).
• Generate change proposal	• Document results of technical evaluation and analysis, generate and communicate change proposal. In some cases CCB or CPCSB approval may be required before proceeding with engineering development.
Engineering Development and Unit Test	
• Develop the change	• Implement the design, coding of computer program changes, establish new OFP baseline, coordinate if also a hardware change.
• Perform engineering tests	• Module/code level testing, create new OFP.

Table 2-1. Post-PMRT OFP Support Requirements (Concluded)

OFP Change Requirement	Remarks
System Integration and Test	
• Test ECS system performance	• Insure that as-coded change satisfied requirements and has no adverse effects on the operation of the unchanged parts of the OFP.
• Test weapon system performance	• Ensure that change or changes satisfy system requirements without adverse effect, includes flight test depending upon nature of change.
• Produce test reports	• Analysis of simulation/flight test and documentation of results.
Change Documentation	
• Document ECS change	• Update specific change.
• Update ECS baseline	• Update ECS specifications and support system specifications as necessary.
• Configuration control	• Establish new baselines for formal control.
Certification and Distribution	
• Certify documentation	• Administrative sell-off/buy-off.
• Distribute revised ECS data	• Prepare and coordinate technical publications.
• Provide installation procedures/ instructions	• Participate in installation of change.
Unique Requirements	
• Nuclear safety design criteria	• Adequate nuclear safety must be designed into the system so that dependence on administrative procedures for providing safety can be minimized.
• Nuclear safety test criteria	• Examine the coding, flows, detailed end-item requirements and weapon system requirement to ensure that the software does not contain improper design, programming, fabrication, or application.

2.2 CHANGE ANALYSIS AND SPECIFICATION

2.2.1 Feasibility

Analyze system specifications, improvements already underway, any proposed system changes to ensure system integrity. Determine any new hardware/software interfaces. Ensure that the requirements are feasible and testable.

2.2.2 Requirements Decomposition/Definition

Examine the requirements imposed by each software change request and determine how they relate to the existing requirements. Determine software, hardware, and system impacts. Examine alternative design approaches. Document results of technical evaluation. In those cases where the change is to be accomplished by contract or with contractor assistance, a change proposal (Requirement 8) will be required.

2.2.3 Preliminary Design

Accomplish preliminary design and testing approach. Determine impact of implementing a change request on the support system. Prepare documentation and conduct Preliminary Design Review (PDR).

2.2.4 Detailed Design

Prepare flow charts, logic diagrams, equations, and narrative description, sufficiently detailed to provide basis for actual coding. Complete definition of data base at the software segment, program, function module, and routine levels; include number, type, and structure of tables and description of items in the tables. Define all elements as critical or noncritical. Develop detailed draft of validation test plan. Conduct Critical Design Review (CDR) to confirm that the design meets its development requirements and is defined sufficiently to permit start of coding.

2.2.5 Generate Change Proposal

This activity documents the change proposal and seeks approval from either the Computer Program Configuration Sub-board (CPCSB) or the Configuration Control Board (CCB) depending upon the nature and extent of the change or changes. This should be a meaningful review and formal approval, not just a management formality.

2.3 ENGINEERING DEVELOPMENT AND UNIT TEST

2.3.1 Develop the Change

Code, debug, and check out the routines. Debugging will ensure compilation and checkout will ensure execution.

2.3.2 Perform Engineering Tests

Conduct testing of coded elements and integrate software segment to produce new master tape.

2.4 SYSTEM INTEGRATION AND TEST

2.4.1 Test ECS System Performance

Conduct testing of entire integrated ECS system, including software developed and tested during development and other interfacing hardware and software. For most OFP changes some form of verification and validation will be necessary. To be effective this should be an independent activity.

2.4.2 Test Weapon System Performance

Test integrated and validated ECS's in the operational environment with all other associated systems. This will usually involve some degree of flight testing for OFP change.

2.4.3 Produce Test Reports

Analyze simulation and flight test results to ensure that the as-coded software changes satisfy the requirements and have no adverse affects on the operation of the unchanged parts of the OFP and ECS. Implicit in their activity is a final review and decision to issue a new release.

2.5 CHANGE DOCUMENTATION

2.5.1 Document ECS Change

Formalize the documentation of the specific ECS change or changes.

2.5.2 Update ECS Baseline

This activity creates the new baseline for the entire ECS through update of appropriate specifications and associated documentation.

2.5.3 Configuration Control

This activity formalizes and controls the new baselines for the OFP and the ECS.

2.6 CERTIFICATION AND DISTRIBUTION

2.6.1 Certify Documentation

Certification is an administrative procedure performed to ensure that enough evidence is available to state with near certainty that the system will satisfy the user's needs. It is performed after the system testing has been completed. Certification embodies all the ECS testing and evaluation, verification, validation, and operational testing and evaluation activities have been performed.

2.6.2 Distribute Revised ECS Data

Distribute revised/updated OFP and related system changes to hardware, support system, training, technical publications, and support documentation.

2.6.3 Provide Installation/Procedures/Instructions

This is the final activity and may require on site assistance in installing or implementing the change.

2.7 UNIQUE SUPPORT REQUIREMENTS

Embedded computer systems that have a first or second level interface to a nuclear weapon as defined in AFR 122-9 fall in a special category. This includes software used by automata which control critical functions of a nuclear weapon (first level interface) or which respond to or transmit information to automata having a first level interface. In this context automata includes automatic processors, microprocessors, computers, decoders, controllers, and may include their associated peripheral equipment. The following requirements are unique to this special category.

2.7.1 Nuclear Safety Design Criteria

Design of an ECS system which has a first or second level interface with a nuclear weapon must include positive measures whose goal is to prevent the malfunction or accident to a single component, and to prevent deliberate action which will cause prearming, arming, launching, jettisoning or releasing nuclear weapons, or producing a nuclear yield except when directed by competent authority.

2.7.2 Nuclear Safety Test Criteria

For ECS having a first or second level interface to a nuclear weapon, a nuclear safety cross check analysis is required. This includes examination of coding, flows, and requirements to ensure that software errors do not contribute to nuclear accidents of the sort described in Section 2.7.1.

3. OFP CATEGORY ECS SUPPORT CONCEPTS

3.1 BACKGROUND

The concept for support of embedded computer system category OFP is known as Avionics Integration Support Facility (AISF). Although engineering laboratories for OFP support were being established in the early 1970's at China Lake NAS for both Navy and Air Force versions of the A-7 and at McClellan AFB for the F/FB-111, the term AISF emerged in the mid-1970's. The initial facilities were established primarily as software (OFP) support facilities because software was believed to be the major problem. However, with the release to Navy field units of the first organically revised OFP by the China Lake facility in early 1974, and for the F/FB-111 later that same year by McClellan, the capability of these facilities was more fully understood. It became apparent particularly during the development and initial operation of the F/FB-111 AISF, that these facilities, depending upon their configuration, could do much more than just support reprogramming of the OFP. This notion was also supported by a growing need and recognition that hardware support as well as system support were equally important and that their support could be accomplished within the AISF concept. Furthermore, with popularization of the terms computer resources and embedded computer systems, the emphasis shifted towards system or ECS support requirements rather than separate concepts and facilities for hardware, software, and system support needs.

3.2 ECS HARDWARE AND SOFTWARE SUPPORT

The current OFP ECS support concept assigns computer equipment (hardware) and computer program (software) support to an Item Manager (IM) or System Manager (SM) with the software support facility (AISF) collocated with and responsive to the weapon system manager.

The OFP ECS category support concept envisions support of computer equipment (hardware) in the traditional sense, i.e., Technology Repair Center (TRC) with computer program (software) support being provided by engineering laboratories (AISF's) established within the engineering divisions at the ALC's. Underlying the concept is an attempt to collocate software management with associated hardware management to retain control over system performance.

3.3 ECS SUPPORT MANAGEMENT

The system manager is responsible for overall weapon system support. He exercises this responsibility directly and through various item managers for hardware support with both the SM and IM ECS computer program support being provided primarily by or channeled through the appropriate engineering organization.

3.4 ECS CATEGORY OFP - AISF CONCEPT

Currently the AISF established within the engineering divisions is described as an engineering laboratory composed of the engineering and scientific capability required to accomplish the requirements listed in Table 2-1. The AISF concept shown pictorially in Figure 3-1, brings together all the tools and skills required for the support of the OFP's resident in the embedded computer systems.

3.5 AISF FUNCTIONS

An AISF, which is normally established for the deployment phase, consists of the equipment, data, and people involved in the continuous process of embedded computer system revision and update throughout the remainder of the weapon system life cycle. To accomplish the support requirements, an AISF provides the capability to

- Identify change requirements for enhancements, mission changes, additions of new sensors/subsystems, and correction of deficiencies/errors
- Establish a management system for review, approval, and control of block changes proven technically achievable

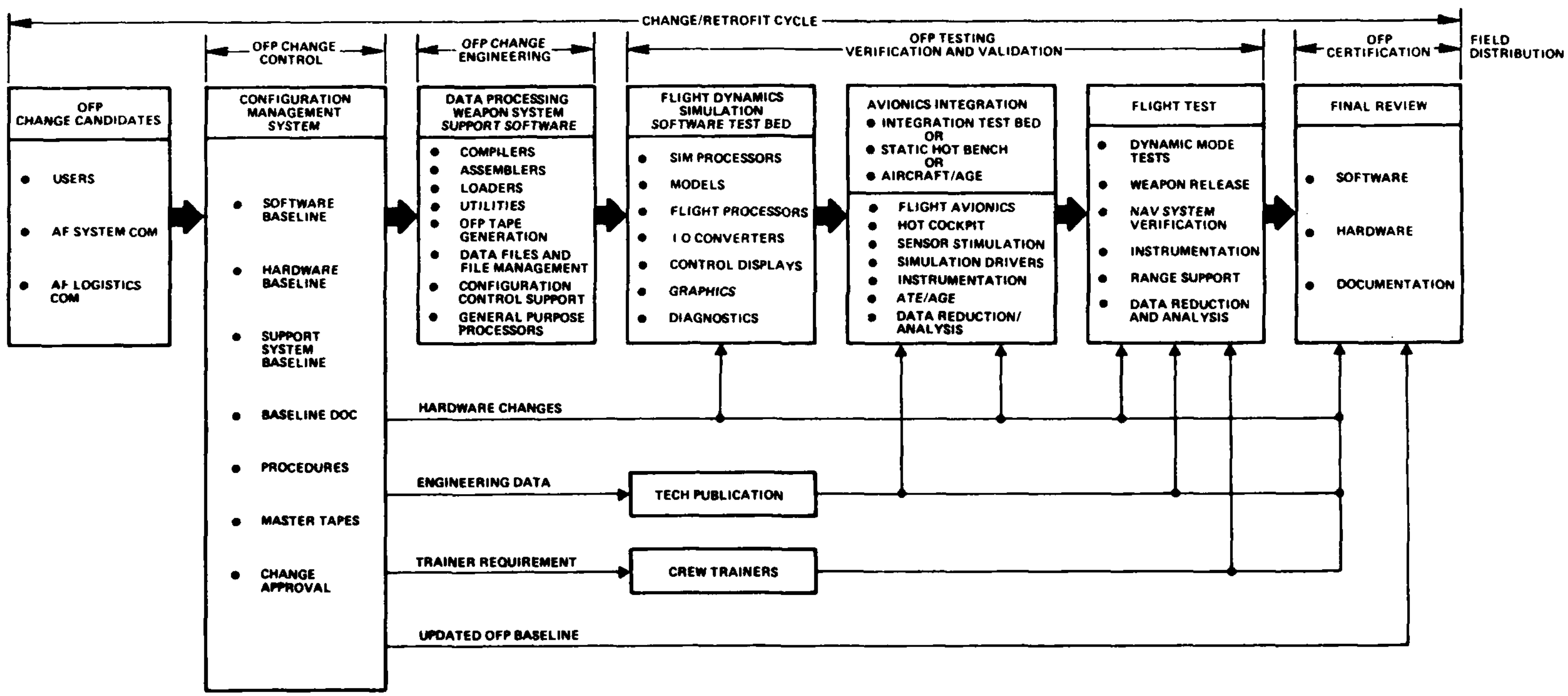


Figure 3-1. Avionics Integration Support Facility (AISF) Functions

- Develop updated/modified OFP's in response to engineering requests and approved changes

- Perform verification and validation (V&V) of change candidates through use of simulation/integration facilities, flight test, and procedures

- Review final development, verification, and flight test results for certification and field release of updated OFP's

- Update related system changes to hardware, OFP support systems, training, technical publications, and support documentation

An important additional functional use of an AISF concerns the capability to support the PMRT process. Depending upon the availability of the AISF or even portions of the AISF prior to PMRT, AFLC can be in a position to support independent assessment of the deliverable systems/products. It can also demonstrate weapon system supportability which is an important part of combat readiness. By participating in the AISF acquisition/development, weapon and support system training is accomplished. Once again, depending upon the completeness of the AISF, AFLC can perform independent verification and validation in conjunction with or prior to PMRT.

3.6 AISF COMPONENTS

The basic components of an AISF are shown in Figure 3-2. This simplified form is used to facilitate delineation and comparison of representative support systems in Section 4. The following paragraphs describe the components of an AISF in terms of

- Host processor (off-line)

- Dynamic simulation system

  - Simulation host processor
  - Hardware interface
  - Flight processor(s)
  - Avionics systems/subsystems

- Flight test

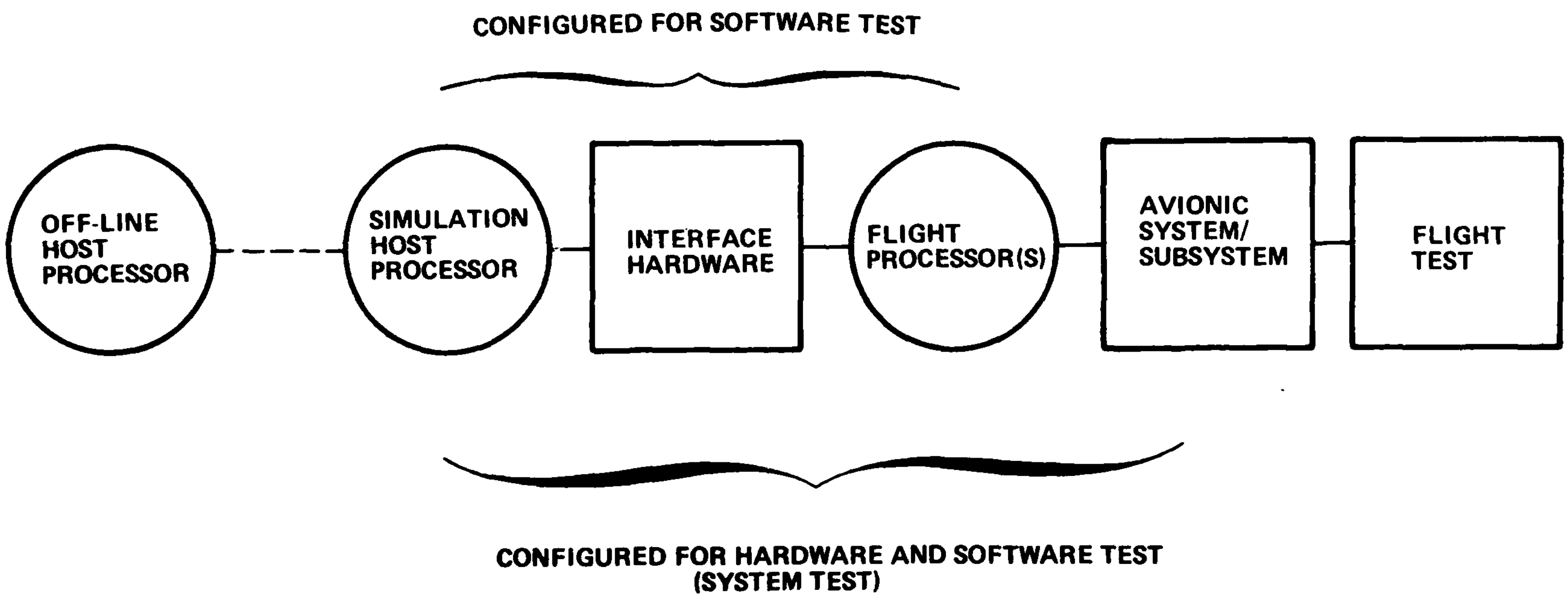


Figure 3-2. AISF Basic Components

3.6.1 Host Processor (Off-line)

Off-line computational capability comprised of medium to large scale computers is used for engineering data management, simulation and flight test data reduction and analysis, configuration management, off-line interpretive computer simulations, various support and debugging tools, cross-assemblers and compilers, special simulation routines, and other software related tasks that can be best accomplished away from the dynamic simulation environment.

3.6.2 Dynamic Simulation System

The dynamic simulation system is made up of a front end mock-up of the weapon system and the following four elements.

3.6.2.1 Simulation Host Processor

The simulation host processor is usually a standard, off-the-shelf, qualified minicomputer and, depending upon its size and capability, may also be used to accomplish many or all of the off-line host processor functions. However, this computer primarily provides the capability to drive the embedded computer flight processor in a real time, closed loop simulation mode and to collect data from the flight computer while the simulation is running. This data can then be used to analyze the performance of the operational software. The software resident on the simulation host processor would include

- Software routines to control and monitor the interface to the avionics embedded computer
- Software routines to process data sent to and from the avionics subsystems
- Simulations for closed loop operation with the operational flight program
- Support software unique to the minicomputer such as compilers, assemblers, and operating systems

3.6.2.2 Hardware Interface

This element between the simulation processor and the flight processor will consist of interface for loading, starting, stopping, monitoring, controlling, simulating, and displaying those functions that are inherent to a dynamic, closed loop simulation of an avionics suite. The hardware interface would normally take the form of

- A computer monitor and control function which interfaces with the internal signals of a flight computer for the purpose of monitoring the flight computer's central processing unit and controlling the operation of the flight computer such as changing its internal status, starting and halting program execution, and like functions

- Hardware interface adaptor units for switching and signal conditioning (D/A and A/D), power distribution, and control

3.6.2.3 Flight Processor(s)

Addition of the flight processor to the simulation host processor and interface hardware results in a Software Test Bed (STB), sometimes called a dynamic simulation system, and provides the capability for OFP testing.

3.6.2.4 Avioncs System/Subsystems

Only those systems/subsystems that affect the operation of the operational program may be required for OFP test. However, if hardware or systems integration and test is the objective, the entire avionic suite may be required. This element, called an Integration Test Bed (ITB), rounds out the ground based engineering laboratory.

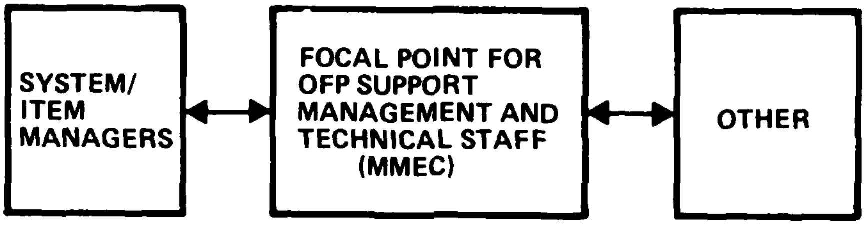
3.6.3 Flight Test

Flight testing requires use of an instrumented aircraft, recording equipment, and an appropriately instrumented flight test range. Flight test is performed for comparison and verification of simulation/integration test results. Data reduction and analysis for both dynamic simulation

cases and actual flight tests can be performed on the off-line host processor or in some cases on the simulation host processor depending upon the relative capabilities of the processors and the configuration of the particular AISF.

3.7 ORGANIZATIONAL CONCEPT

The organizational concept and major interfaces required for OFP support are shown in Figure 3-3. The concept establishes MMEC within the engineering division as the computer resource focal point. The organizational relationships both internal and external to the ALC are defined in the various Computer Resources Integrated Support Plans (CRISP) and Operational/Support Configuration Management Procedures (O/SCMP) for each individual weapon system ECS. Organizational relationships are further discussed in Section 4 "Representative Systems and Support Systems."



- SYSTEM PERFORMANCE
- SYSTEM INTEGRITY
- ECS HARDWARE
- SUPPORT SYSTEM HARDWARE
- SUPPORT SYSTEM SOFTWARE
- AUTOMATIC TEST EQUIPMENT
- AIRCREW TRAINING DEVICES
- COMMUNICATIONS ELECTRONICS
- ELECTRONIC WARFARE

- USERS
- TEST RANGES
- PUBLICATIONS
- FACILITIES
- PERSONNEL
- FUNDING
- CONTRACTOR(S)

Figure 3-3. OFP Support Management/Technical Interfaces

4. REPRESENTATIVE SYSTEMS AND SUPPORT SYSTEMS

A more detailed investigation and analysis of representative weapon systems with emphasis on their support systems is presented in this section. The selection of both aircraft and missile systems within the OFP ECS category was made to ensure the broadest possible coverage of the category to establish the current support baseline. The systems selected along with rationale for their selection follows:

- F/FB-111 - first highly integrated aircraft weapon system to reach operational status; multi-mission; operated by two MAJCOMS; has major digital subsystems (PAVE TACK, SRAM); the support system is operational.
- F/RF-4 - first major digital update (Class V modification) to an existing weapon system; multi-mission; both the ECS and support system are in acquisition.
- F-16 - first major weapon system in acquisition concurrent with or subsequent to DOD and Air Force ECS policy and guidance initiatives; multi-national ownership and use; both the weapon and support system are in acquisition.
- Minuteman II/III - major unmanned weapon system; involves nuclear weapons; PMRT long after system was operational.

4.1 F/FB-111 WEAPON SYSTEM DESCRIPTION

The F/FB-111 is a twin engined, high performance, variable geometry fighter bomber. Its primary mission role is precision bombing and all weather night attack. The FB-111A has the additional capability for strategic nuclear weapons delivery. The F-111D, F-111F, and FB-111A have highly integrated digital avionics suites. Major avionic differences are the doppler radar and moving map display on the FB-111A and F-111D; an astrocompass and SRAM on the FB-111A; and a digital stores management system, an advanced display capability, and an attack radar on the F-111D.

These three aircraft use common digital, reprogrammable computers (2 IBM 4 pi, 16 bit, 16K word) and a common analog to digital converter, multiplexer set. The different capabilities of the three aircraft are achieved through differing mechanization of the OFP's resident in the Weapon Delivery Computer (WDC) and the General Navigation Computer (GNC).

4.1.1 F/FB-111 Embedded Computer Systems

The avionic functions of the F/FB-111 aircraft series are accomplished through incorporation of a highly interactive and integrated embedded computer system. The operational flight programs for each aircraft reside in the general navigation computer, the weapons delivery computer, and the navigation computer (NCU) with the OFP's within the GNC and WDC performing the operations which integrate and control the avionics system. The GNC, WDC, and NCU interface with a multiplexer converter which in turn interfaces with the various avionic functional elements. A diagram of the computer equipment and computer program functions integral to the F/FB-111 are shown in Figure 4-1. In Figure 4-2 a simplified version of the ECS shows both the generic functions and F/FB-111 nomenclature.

4.1.2 F/FB-111 OFP Change Process

A block change consists of a number of OFP changes which are concurrently processed and integrated into a new baseline OFP over a specified period of time. The F/FB-111 block change process is shown in Figure 4-3 and summarized in Table 4-1 for ease of comparison with other representative system change processes. These changes affect only the OFP and are accomplished within the current ECS hardware baseline. The number of changes attempted in any given cycle is a function of user-established priorities and complexity or difficulty of the proposed change. Flexibility in the change process is achieved by providing for unplanned or out of cycle changes depending upon user urgency and a "Configuration Freeze" late in the change cycle.

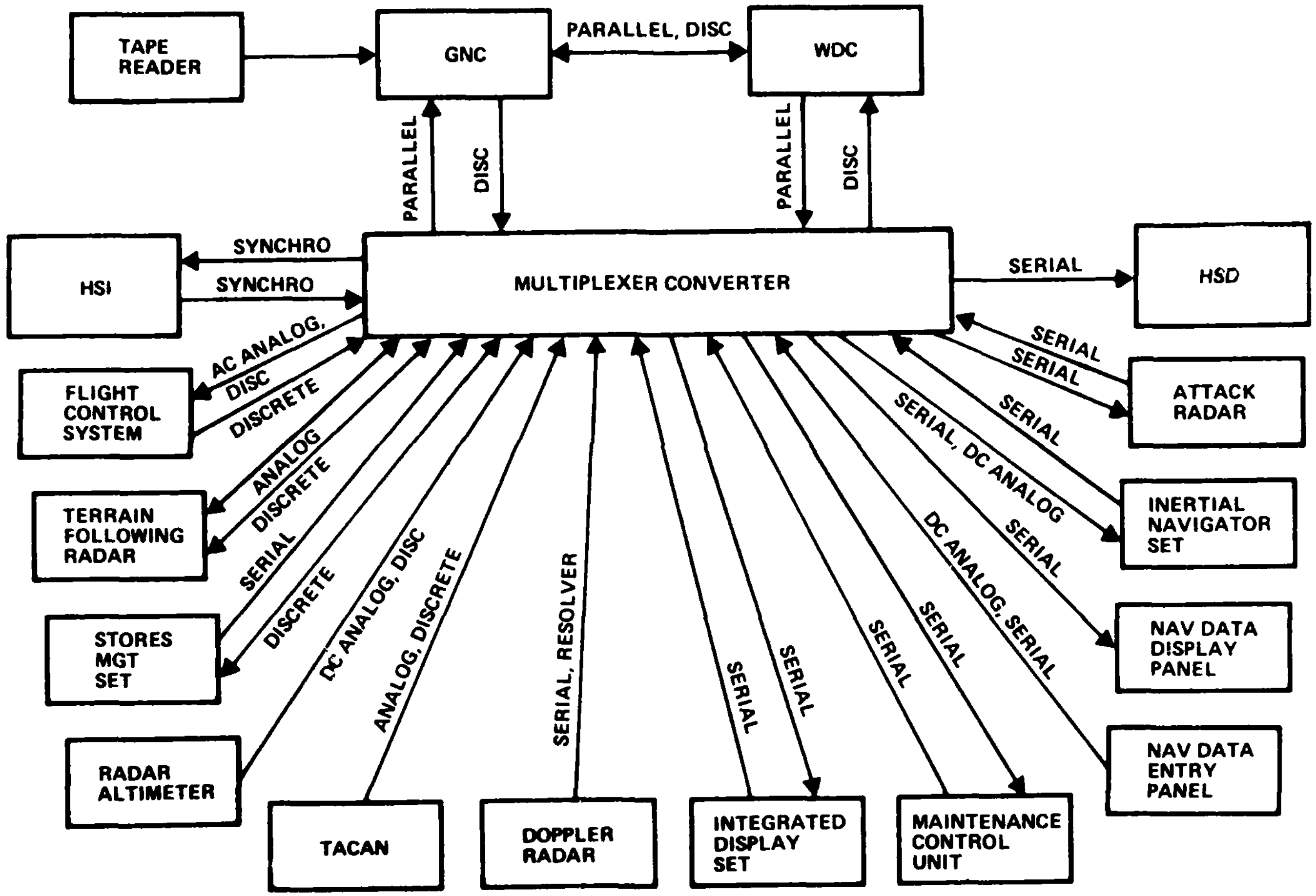
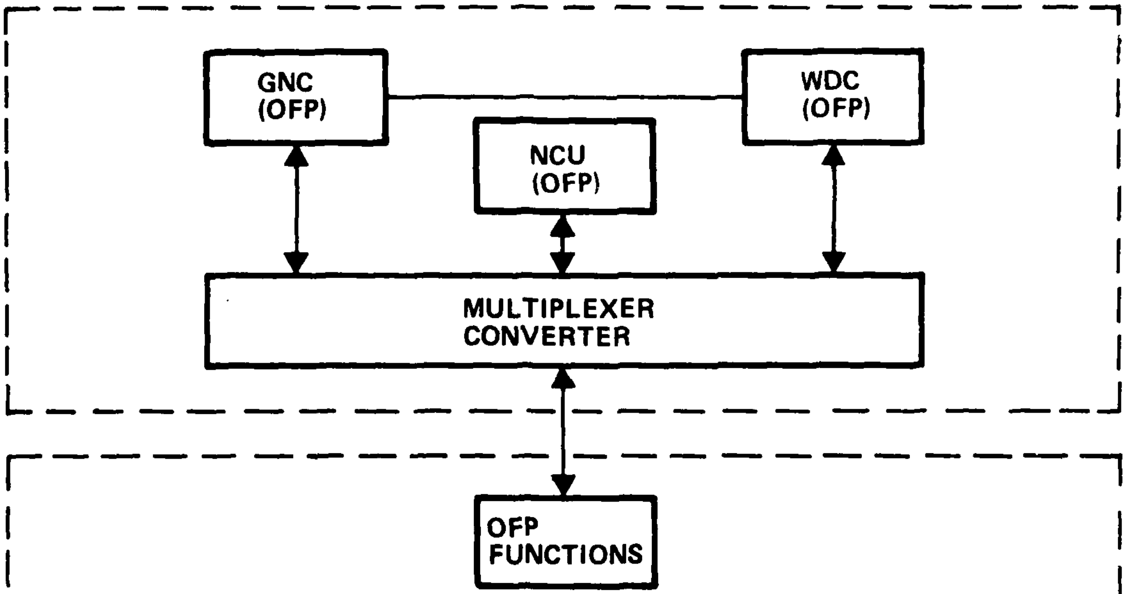


Figure 4-1. F/FB-111 Avionics System

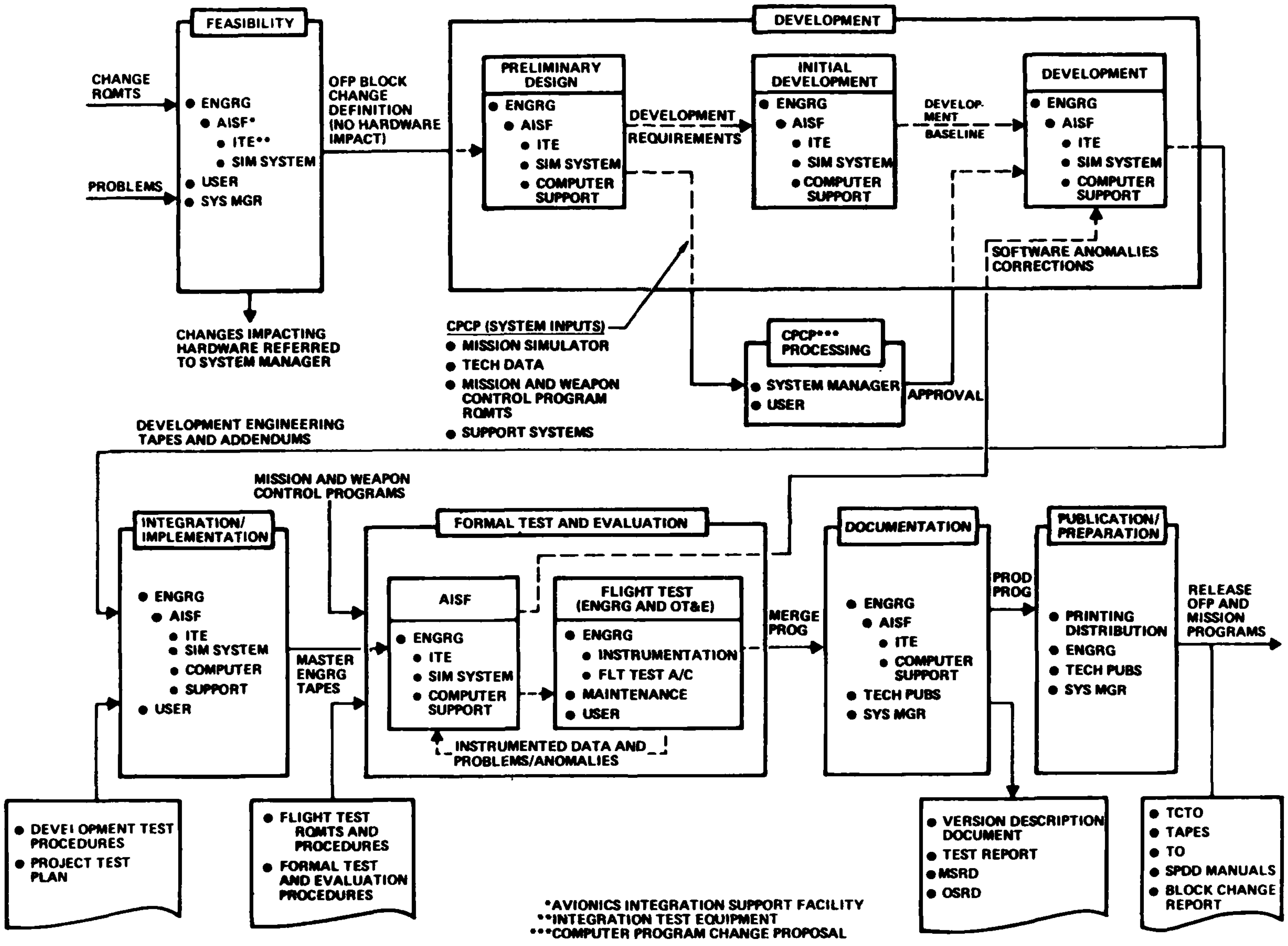


GENERIC NAME	F/FB-111 NOMENCLATURE
• NAVIGATION	• GENERAL NAVIGATION • INERTIAL NAVIGATION SET • NAVIGATION DATA ENTRY PANEL • TACAN
• CONTROLS AND DISPLAYS	• INTEGRATED DISPLAY SET • NAVIGATION DATA DISPLAY PANEL • HORIZONTAL SITUATION DISPLAY
• RADAR	• ATTACK RADAR • DOPPLER RADAR • RADAR ALTIMETER • TERRAIN FOLLOWING RADAR
• WEAPON CONTROL/ DELIVERY	• WEAPON DELIVERY • STORES MANAGEMENT SET
• FLIGHT CONTROL	• FLIGHT CONTROL SYSTEM • HORIZONTAL SITUATION INDICATOR • CENTRAL AIR DATA
• BUILT-IN-TEST	• SELF-TEST

Figure 4-2. F/FB-111 Embedded Computer System

Table 4-1. F/FB-111 OFP Block Change Cycle (18 Months)

Phase/Support Requirement	Engineering Activity	Primary Output/Control Documentation
Feasibility	• Review of change requirements	• OFP block change requirements
Development	• Preliminary/design • Initial development • Development	• Computer Program Change Proposal (CPCP) • CPCP approval • Project test plan • Flight test requirements • Finalize and test each DFP change
Integration and Implementation	• Laboratory integration and test • User demonstration	• Formal test procedures • Master engineering program tape and listing produced • Laboratory and flight test configuration established • Mission and weapon control program produced • Laboratory verification and evaluation completed
Formal Test and Evaluation	• Three phase laboratory test • Instrumented engineering flight test • User Operational Test and Evaluation (OT&E) • Review test results	• OFP block change configuration freeze • To source data V&V • Mission simulator source data finalized and delivered • Engineering OFP release tape produced
Documentation	• Engineering documentation is finalized	• Final test report • Version description document • System program description document • Master software requirements document • Technical order master prepared
Publication and Preparation for Release	• Engineering documentation and technical orders published	• OFP block change report



*AVIONICS INTEGRATION SUPPORT FACILITY
**INTEGRATION TEST EQUIPMENT
***COMPUTER PROGRAM CHANGE PROPOSAL

Figure 4-3. F/FB-111 OFP Change Process

The duration of the change cycle (currently 18 months) is rigidly adhered to and is based on several considerations including user request, support resources, related system updates, crew training, and lead times for documentation update. The OFP block change process is continuous, with each block change containing only OFP changes which do not impact hardware, can be accomplished within existing resources, and do not disrupt the scheduled cycle time.

4.1.3 F/FB-111 OFP Support Interfaces

The F/FB-111 block change process is highly technical with extensive engineering oriented interaction internal to the engineering organization as well as external, such as with the system manager and user. In the case of the F/FB-111, three OFP change cycles involving seven OFP's are in progress continuously and simultaneously in support of the FB-111A, F-111D and F-111F. The engineering organization (MMEC) owns and supports the AISF with MMECP responsible for the technical management, planning, and direction of the complete OFP change cycle, and for the development and implementation of all OFP changes. The primary organizational interfaces for OFP support are the system manager in coordination with the users (TAC and SAC) for operational requirements and internal to AFLC/ALC for other requirements such as personnel, facilities, equipment, contracting, and technical publication.

4.1.4 F/FB-111 OFP ECS Hardware Support

Determining whether or not, or to what extent, ECS hardware is impacted is normally accomplished during the feasibility phase. This activity may require use of the full range of equipment and skill available in the support facility. Once the determination is made that a proposed change requires both ECS hardware and software modification or just hardware, the engineering package is referred to the systems manager for processing in accordance with hardware procedures. However, this does not preclude accomplishing the OFP portion of the change by the OFP support facility.

In addition to isolation of problems to hardware or software or determining the impact of proposed changes to hardware or software, hardware support is provided by the OFP support facility in the area of simulation for a wide variety of equipment malfunctions, failures, and degraded performance. This capability is also applied to analysis of troublesome items that are cleared by normal test and repair procedures but do not perform in the operational environment.

4.1.5 F/FB-111 OFP ECS Software Support

The engineering activities required during the OFP change process are under the direction of MMEC and are accomplished in an engineering laboratory located at SM-ALC. This laboratory and associated facilities and equipment, which are described in the following paragraphs, consists of:

- Off-line computer support
- Dynamic simulation
- Avionics integration
- Instrumented flight test aircraft
- Subsystem test

4.1.5.1 Off-line Computer Support

The off-line computational support required for changing/modifying F/FB-111 OFP's is provided by use of two Interdata 8/32 minicomputer systems and a PDP 11/40 minicomputer system. Additional capability is provided by a remote terminal to an IBM 360-65 computer complex located at OO-ALC. This facility is presently the only source available for OFP assemblies.

4.1.5.2 Dynamic Simulation

Separate dynamic simulation systems for the F-111D and FB-111A/F-111F provide a laboratory capability to exercise the flight computers with resident OFP's in a fidelity simulated flight environment. Each simulation system equipment configuration consists of host processors,

special interface hardware, the actual flight computers with their OFP's, and an aircraft cockpit which also serves as a test station. The major elements of the avionic integration support facility are depicted in Figure 4-4. The dynamic simulation system complex is shown in Figure 4-5 and in simplified form in Figure 4-6 for ease of comparison to subsequent discussions of the other dynamic simulation systems.

4.1.5.3 Avionics Integration

Avionics integration equipment in the F/FB-111 AISF provides the capability to do static integration and test of the revised OFP's with the avionics system. This integration test equipment (ITE) is for the most part the same equipment used during the initial development of the OFP's. Therefore, it can be used for on-line implementation and evaluation of trial solutions as well as final system compatibility tests. The ITE also provides the means to recreate flight problems and check hardware/software interfaces. This equipment is used extensively throughout the OFP change process.

4.1.5.4 Instrumented Flight Test Aircraft

The final check on revised OFP performance is accomplished by actual flight test. The flight test capability includes aircraft equipped with instrumentation designed specifically for monitoring and recording OFP flight performance. Combined with associated data reduction and analysis equipment in the support facility, this is used for final definition and verification of ECS performance.

4.1.5.5 Subsystem Test

The F/FB-111 AISF also contains a subsystem test area. This capability is ECS hardware oriented and has evolved as an extension to the basic software support capability envisioned in the original implementation plans. The primary motivation for acquiring this capability stems from an ECS subsystem support viewpoint rather than just a software viewpoint. It is described by SM-ALC personnel as a necessary part of the support facility in terms of the "total utility" of the F/FB-111 AISF. Basically, it provides in the support facility the capability for

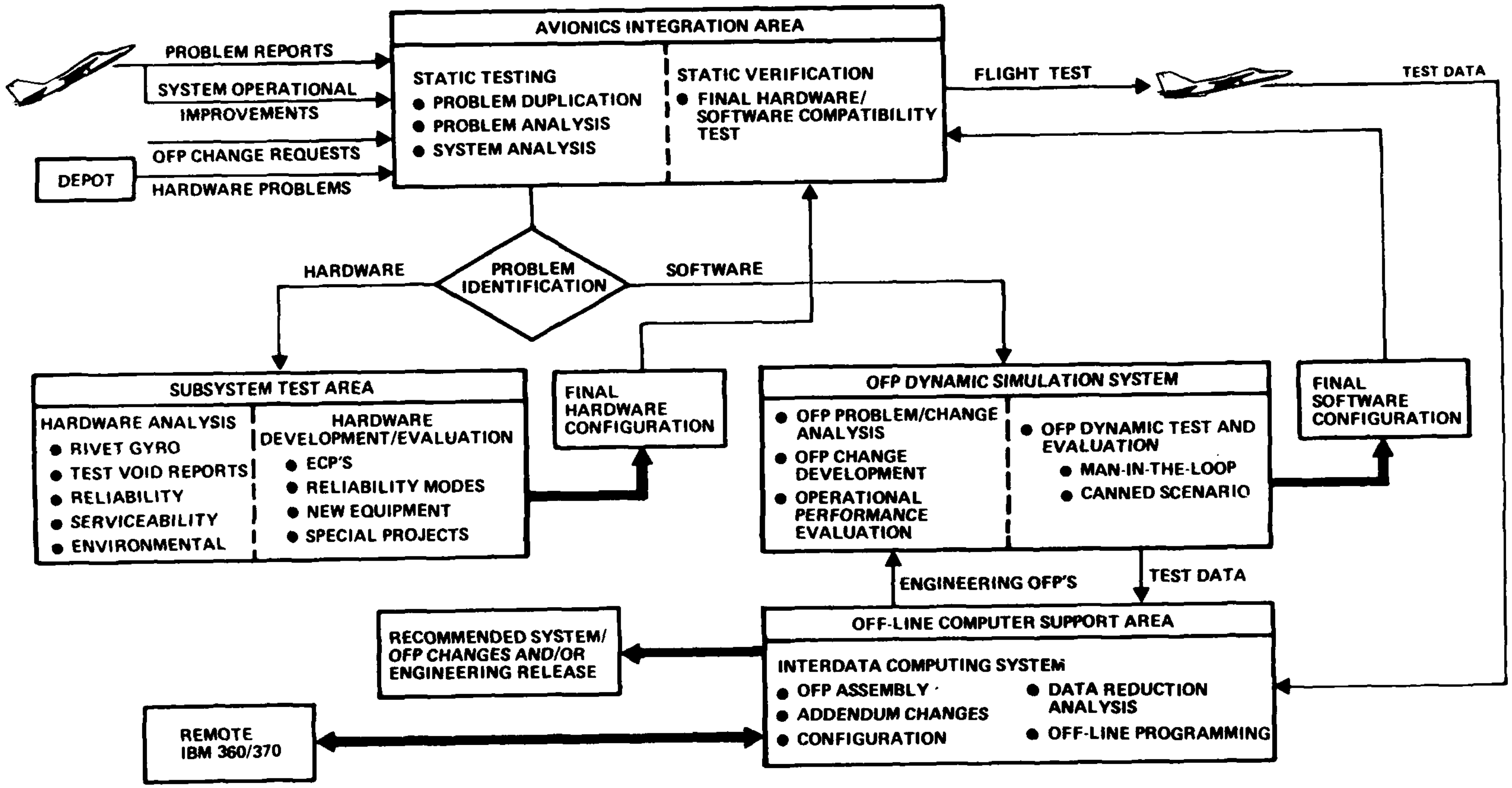


Figure 4-4. F/FB-111 Avionics Integration Support Facility

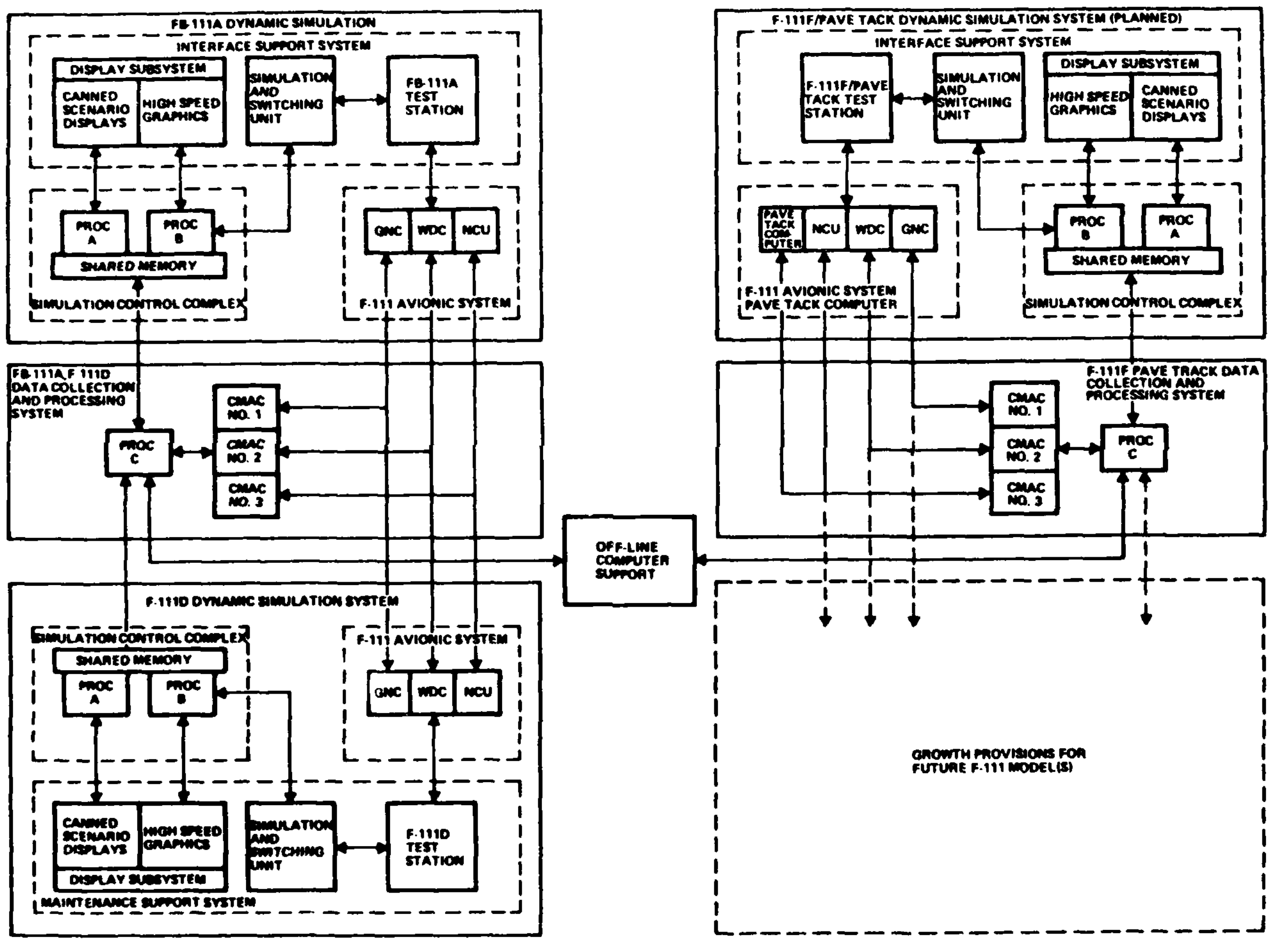


Figure 4-5. F-111 OFP Dynamic Simulation System Complex

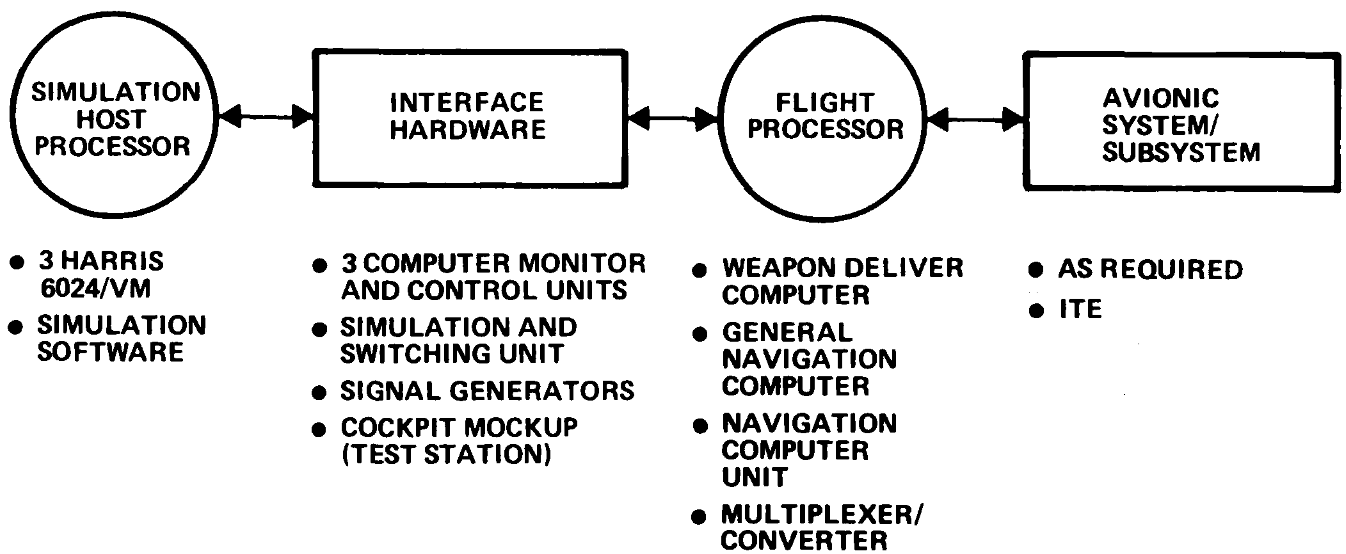


Figure 4-6. F-111D and FB-111A/F-111F Dynamic Simulation

ECS hardware analysis in a problem isolation or problem solving mode. It also provides a test bed environment for hardware development/evaluation with regard to new ECS replacement hardware as well as development of special tools or equipment in the area of ECS hardware reliability, test, and maintenance. This capability is largely microprocessor based and is versatile in supporting new subsystems under development which incorporate distributed microprocessing. Microprocessors are also presently used to reduce several of the large subsystem testers to two-man portable test aids for the F/FB-111. These test aids, with minor modification, have applicability to other embedded computer systems. The number and type of microprocessor development systems is presented in the automatic test equipment baseline.

4.1.5.6 Assessment of F/FB-111 Support Posture

The F/FB-111 AISF provides comprehensive software support to the F-111D, F-111F and FB-111A. The equipment is up-to-date with only minor limitations due to some dependency on remote off-line host processor support. MMEC is responsible for OFP changes and maintaining the support facilities. Automated tools for documentation and configuration management are needed. The AISF is managed and controlled by government personnel with technical staffing consisting largely of on-site contractor personnel with back-up at contractor facilities. The experience level of both government and contractor personnel is high. Future plans call for the development of a unique F-111F/PAVE TACK dynamic simulation system for support of the F-111F and the PAVE TACK interface. Support for PAVE TACK will be accomplished on the PAVE TACK AISF at WR-ALC. The AISF, although operating essentially at a level of effort, is postured for and is providing effective and responsive OFP support and is gradually extending its capability for a broad range of ECS support tasks.

The F/FB-111 AISF provided the basis for the emergence of the current AISF concept and is now extending the concept into a wider support role in the area of avionics hardware support and by extending the AISF to the flight line through development and support of portable test tools and aids. Findings/remarks concerning the F/FB-111 AISF current capability to support the requirements are presented in Table 4-2.

4.2 F-16 WEAPON SYSTEM DESCRIPTION

The F-16 is a single engined, high performance fighter bomber. Its primary mission role is air superiority and precision bombing. Procurement and production is being accomplished according to a June 1975 memorandum of understanding between the government of the United States and the governments of Belgium, Denmark, the Netherlands, and Norway.

The aircraft weapon system uses seven digital computers/ microprocessors including a reprogrammable Fire Control Computer (FCC), (Delco 362F-2, 16 bit, 32K word) which serves as a central computer. The fire control computer OFP implements, integrates, and controls avionic system functions. The other airborne processors are firmware reprogrammable.

4.2.1 F-16 Embedded Computer System

The avionic functions of the F-16 aircraft are distributed and communicate over a dually redundant MIL-STD 1553 multiplex bus system under primary control of the fire control computer, with backup bus control in a degraded mode provided by the Inertial Navigation Set (INS). The bus controller, primary or backup, initiates all traffic over the data buses by issuing commands to remote terminals (avionic subsystems) to transmit or receive data and also determines the bus (A or B) to be used for the transmission. The AN/ALR-69 threat warning system is a reprogrammable radar warning system which is not connected to the multiplex bus. This system is discussed further in the Electronic

Table 4-2. F/FB-111 Support Status

Requirement	Findings/Remarks
ECS Change	Procedures were established over a period of time, are thorough and well implemented. Change candidates and corresponding workloads negotiated with user essentially to conform with predetermined resource expenditures.
Change Analysis and Specification	Activities and procedures are formalized and comply with AFR 800-14. Locally developed procedures and terminology often do not easily relate to similar activities of development command.
Engineering Development and Unit Test	Activities generally conform with standard development practices. Terminology sometimes misleading, i.e., PDR and CDR not mentioned. Block change configuration not established until test phase.
System Integration and Test	Integration and test is thorough and comprehensive with extensive user involvement.
Change Documentation	ECS and support system baselines documented. Some locally developed documents also maintained such as Master Software Requirements Document (MSRD). Documentation including technical order preparation is primarily manual and accomplished at both government and contractor facilities.
Certification and Distribution	System manager certifies and approves revised programs for release. The use of standard ALC technical publication is time consuming (4 to 6 months) and impairs responsiveness.

Warfare (EW) ECS category. A diagram of the computer equipment and computer program integral to the fire control computer in the F-16 is shown in Figure 4-7. A simplified diagram of the F-16 ECS is shown in Figure 4-8.

4.2.2 F-16 OFP Change Process

The OFP change process used by the program office during full scale engineering development will be used until PMRT. After PMRT the OO-ALC computer program configuration sub-board chaired by the F-16 system manager is to have approval and release authority for all CPCI Class I and II software changes which do not affect system equipment and can be accomplished within existing support resources. Operational flight program updates are planned to occur at approximately 18 month intervals. Changes which involve both hardware and software modifications are to be scheduled on a case by case basis, processed as ECP's for approval, and implemented in accordance with existing AFLC procedures. No change to existing AFLC procedures is envisioned for ECS hardware changes. The proposed OFP block change cycle is shown in Figure 4-9 and in tabular form in Table 4-3.

4.2.3 F-16 OFP Support Interfaces

The F-16 OFP change/modification process is highly technical with extensive engineering oriented activity both internal to Ogden ALC and external to the user and other support agencies. As a multinational use weapon system, additional interfaces are necessary particularly at the system manager level. This interface will become even more important should the F-16 become involved in Foreign Military Sales (FMS).

Current plans call for the system manager to be responsible for all tasking and system integration including establishing priorities and coordination of system integration efforts. This office also has

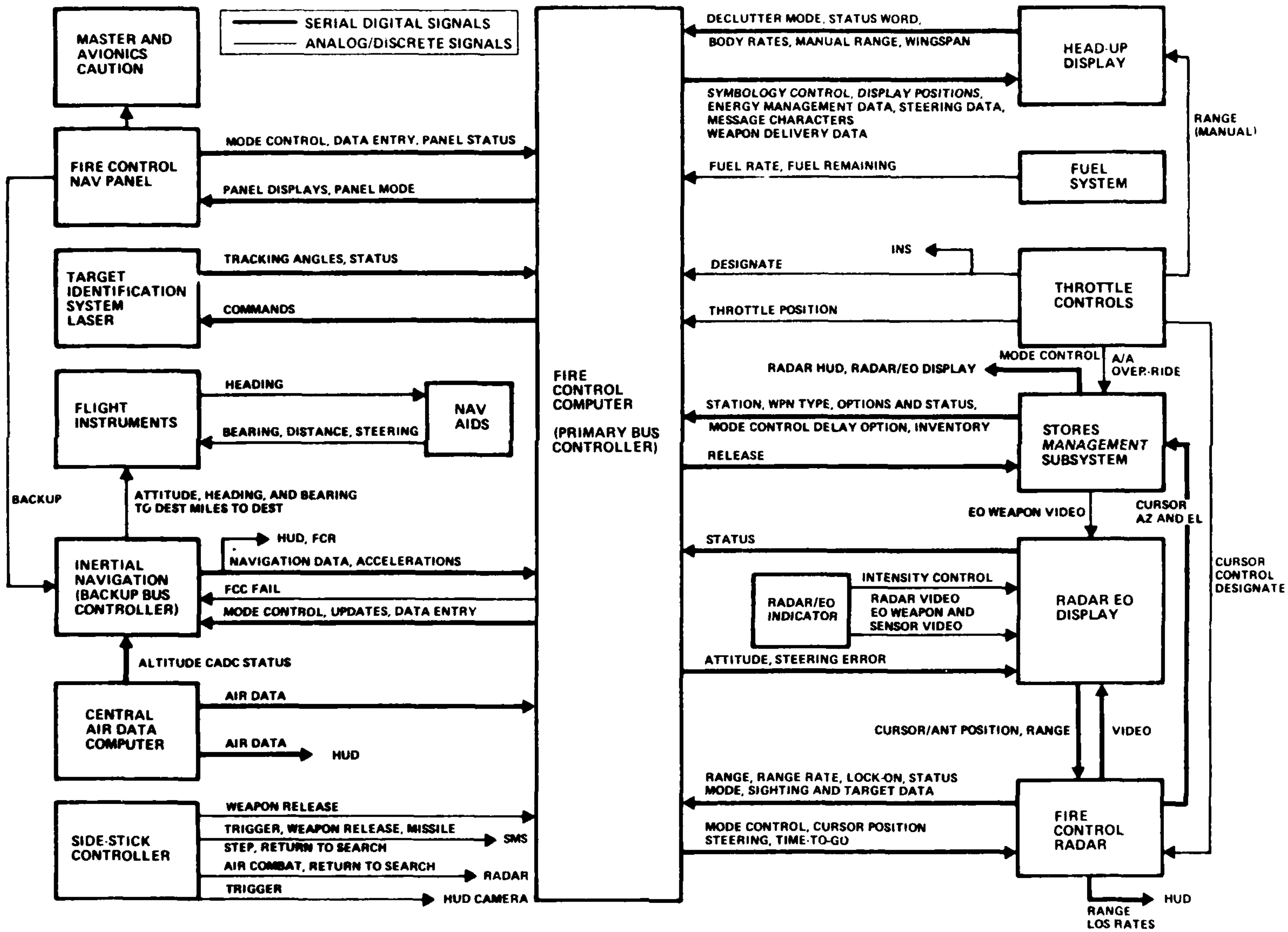
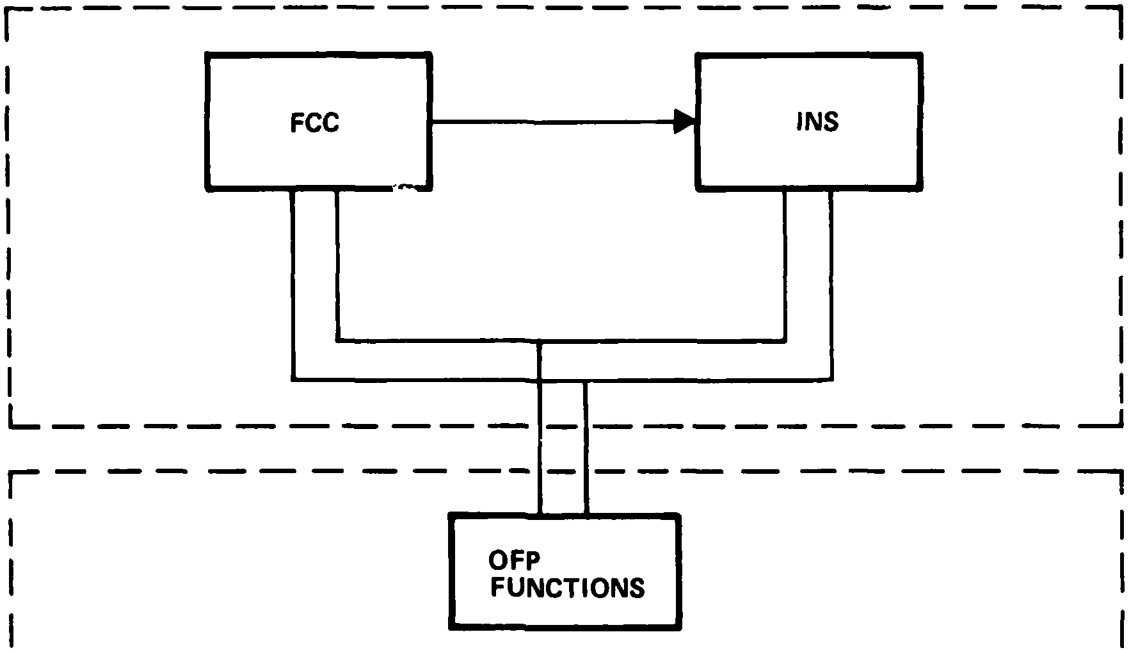


Figure 4-7. F-16 Fire Control Subsystem



GENERIC NAME	F-16 NOMENCLATURE
• NAVIGATION	• INERTIAL NAVIGATION
• CONTROLS AND DISPLAYS	• HEAD UP DISPLAY • RADAR EO DISPLAY • FIRE CONTROL NAV PANEL • MASTER AND AVIONICS CAUTION
• RADAR	• FIRE CONTROL RADAR
• WEAPON CONTROL/ DELIVERY	• FIRE CONTROL • STORES MANAGEMENT SYSTEMS • TARGET ID SYSTEM LASER
• FLIGHT CONTROL	• FLIGHT INSTRUMENTS • SIDE STICK CONTROLLER • THROTTLE CONTROLS • CENTRAL AIR DATA
• FLIGHT RECORDING	
• ENGINES	• FUEL SYSTEM
• BUILT-IN-TEST	• BUILT-IN-TEST

Figure 4-8. F-16 Embedded Computer System

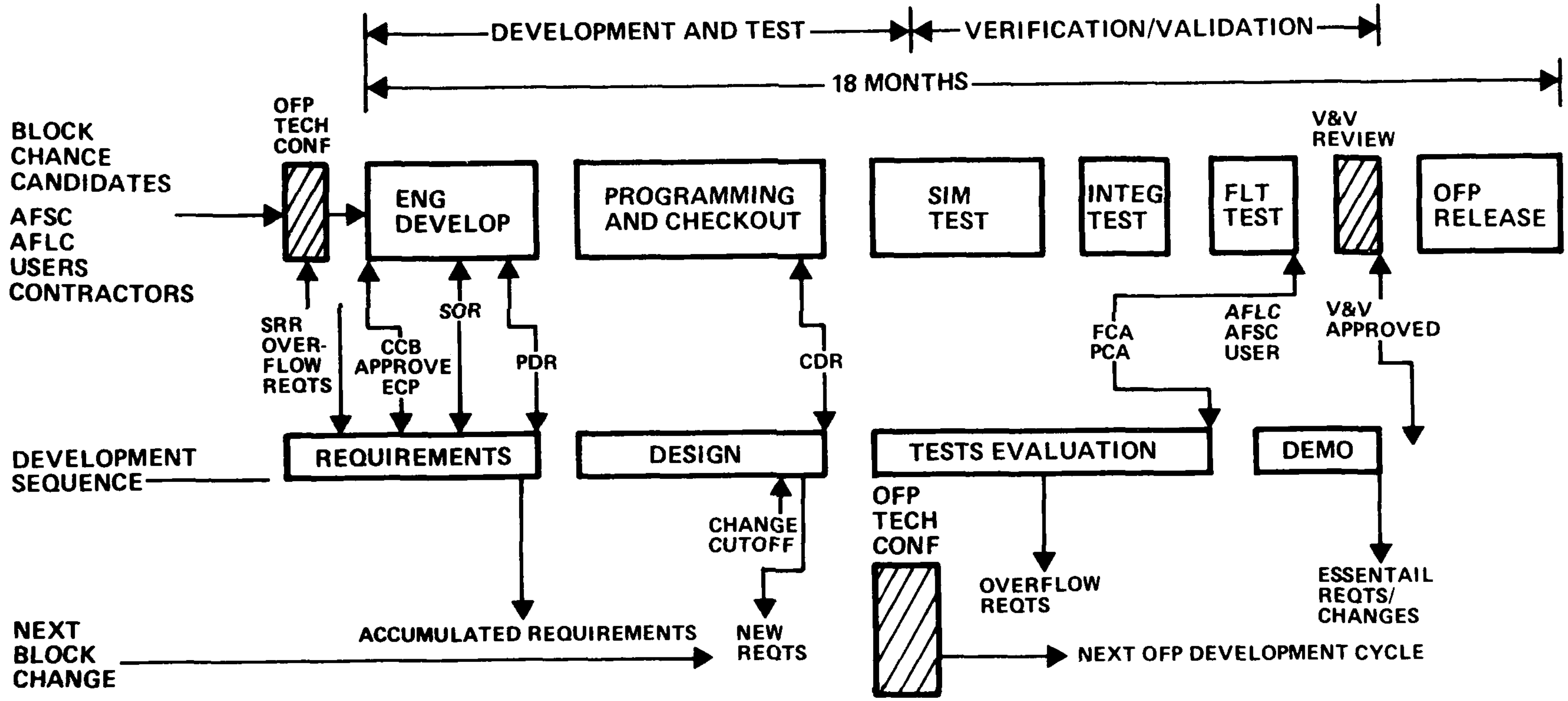


Figure 4-9. F-16 OFP Update Cycle (Planned)

Table 4-3. F-16 Proposed OFP Block Change Cycle (18 months)

Phase/Support Requirement	Engineering Activity	Primary Output/Control Documentation
Joint Technical Conference	• Review of accumulated change requests • Feasibility studies • Engineering tests • Revise preliminary ECP's	• Define requirements • Establish priorities • Approve proposed changes • Functional baseline • System design review • General test plan • Test bed program plan
Requirements	• Engineering development	• Computer program development specifications • Preliminary design review • Trainer modification requirements definition • Configuration control
Design	• Programming and checkout • Technical order and OFP documentation	• Critical design review • Change cutoff • Trainer modification
Test and Evaluation	• Simulation test • Integration test • Flight test • Test results analysis • Technical order verification	• Functional configuration audit • Physical configuration audit
Demonstration	• Joint V&V review	• V&V approval • User acceptance
OFP Release	• Technical publication • Documentation	• SM approval

responsibility for establishing the weapon system support facilities. Internal to OO-ALC significant pre- and post-PMRT support is planned to be provided to the SM as follows:

- Computer Resources Branch (MMEC) - provide engineering support for identifying procurement and integration of OFP test equipment and in the post-PMRT time period for problem resolution, feasibility assessment, software design and development, test planning, testing, and evaluation of test results.

- Specialized (Test) Engineering Branch (MMEI) - own and maintain AISF equipment and facilities; provide management and schedule of AISF operation and flight test functions including preparation of test reports.

- Logistics Section, Data Automation Branch (ACDC) - provide system analysts and mathematicians for non-ATE support software required for AISF procurement and integration; during the post-PMRT time period perform the maintenance/ modification of the acquired or developed support software.

4.2.4 F-16 OFP ECS Hardware Support

The embedded computer system support facilities planned for the F-16 are primarily focused on support of the operational flight programs. However, plans include extensive use of the dynamic simulation and integration capabilities for ECS hardware problem analysis and isolation. Once problems are isolated to hardware, the item is referred to the appropriate SM/IM for resolution according to standing AFLC procedure. In those cases where modification is required to both hardware and software, the software support facility is expected to play a major role in the software change as well as in the integration and test of the approved modification at both the component and ECS level.

4.2.5 F-16 OFP ECS Software Support

Ogden Air Logistics Center is presently acquiring the engineering capability (equipment and personnel) required to support the F-16 operational software. Currently the Avionics Intermediate Shop (AIS) automatic test equipment is colocated with the evolving AISF in building 1211. Plans envision that this total complement of equipment when

operational will be used in the post-PMRT time period to provide support for F-16 avionics hardware, software, and Automatic Test Equipment (ATE) engineering requirements. This section, however, is limited primarily to discussion of the equipment configuration being assembled for support of the fire control computer OFP. The engineering laboratory and associated facilities and equipment, which are described in the following paragraphs, consist of:

- Off-line computer support
- Dynamic simulation
- Avionics integration
- Instrumented flight test aircraft
- Subsystem test

4.2.5.1 Off-line Computer Support

The IBM 360-65, resident at Ogden ALC is slated for off-line computer support. The Digital Equipment Corporation (DEC)-10 system general purpose processor, which is the host processor incorporated in the dynamic simulation system, is also being evaluated for use for full or partial off-line software development and post-simulation data reduction and analysis. The DEC-10 is in place in building 1211.

4.2.5.2 Dynamic Simulation

The dynamic simulation system being acquired for the F-16 fire control computer OFP is a highly integrated and complex system consisting of the DEC-10 system host processor, discussed above, interfaced to the fire control computer and OFP through interface hardware units and three major computer controlled/driven hardware based subsystems. The first of these subsystems, called control and monitoring, uses a PDP-11/34, provides control of the operator test station, and effects the multiplex bus interface (universal remote terminal) to the DEC-10 simulation host computer. The performance monitoring subsystem uses a PDP-11/55 and associated peripherals to tie in a Software

Control and Display Unit (SCADU), a Bus Monitor Unit (BMU), and a Digital Data Recorder (DDR) and to provide interface with the control and monitoring PDP-11/34.

The third subsystem referred to as the DSS head up display/ terrain simulation subsystem also uses a PDP-11/55 to provide real time graphics for head up display symbology and three dimensional perspective transformations. The subsystem is interfaced to the DEC-10 system host processor for direct memory access to simulation data. A simplified diagram of the F-16 dynamic simulation system is shown in Figure 4-10 and in a different format in Figure 4-11.

4.2.5.3 Avionics Integration

Another major element planned for integration with the DSS is the Avionics Equipment Bay (AEB). The AEB is a replica of the forward section of the F-16 and contains cables, controls, and actual avionics Line Replaceable Units (LRU's). The AEB also includes an Alpha-16 minicomputer which permits stand alone software and hardware integration and test for individual LRU's with partial/selective simulation or full up avionic system integration and test depending upon the test bed configuration or particular integration or test objectives.

4.2.5.4 Instrumented Flight Test Aircraft

Ogden Air Logistics Center plans for use of a dedicated F-16A production configured aircraft with standard avionics for systems and ECS testing. This EI coded aircraft would be assigned to the Specialized (Test) Engineering Branch (MMET) of the Service Engineering Division and be instrumented to facilitate testing for system engineering, failure analysis, prototyping, and support equipment. Plans call for the use of the Utah test and training range for the majority of the flight tests with data reduction and analysis being accomplished on the IBM 360-65 or the DEC-10 system DSS host processor, depending upon the outcome of the cost effectivity evaluation.

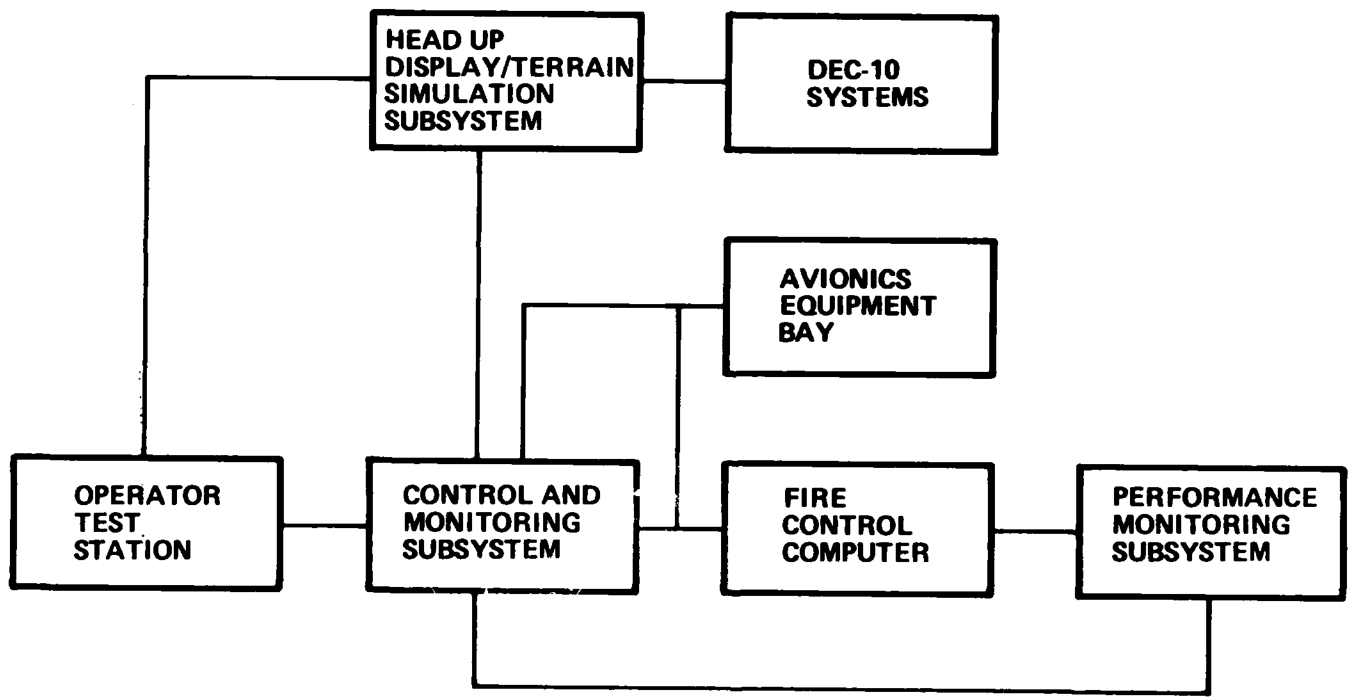


Figure 4-10. F-16 Dynamic Simulation System Configuration (Planned)

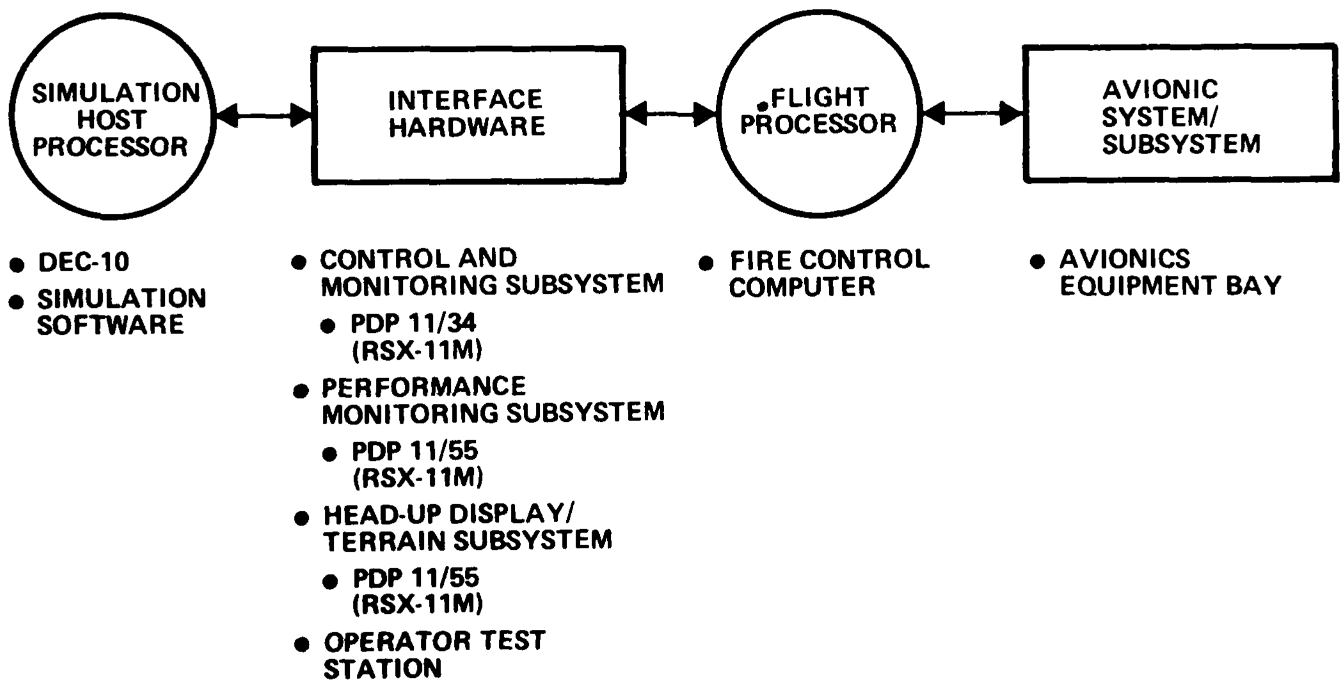


Figure 4-11. F-16 Dynamic Simulation System

4.2.5.5 Subsystem Test

In addition to the DEC-10 system based dynamic simulation system for the fire control system OFP, similar OFP software Dynamic Test Consoles (DTC) are planned for the Stores Management Set (SMS) and the Head Up Display (HUD). Other subsystem test facilities are also planned as follows:

- Radar Engineering Stand (RES) - computer controlled console similar to the one used by Westinghouse for initial system development of the six LRU's which make up the F-16 radar. Primarily for hardware test.
- Intel MDS-800 system - software preparation/development station for support of avionics subsystems containing 8080 based microprocessors. Direct OFP support is primarily for the stores management system with other support planned for automatic test equipment and avionic intermediate shop hardware.
- Electrical Standards Set (ESS) - calibration and test equipment for support of the AIS. This is ATE related and is associated with the AISF, primarily because of its physical location.

Separate dynamic test stands or consoles as part of the AISF are not currently planned for software support of the Inertial Navigation Set (INS), Central Air Data Computer (CADC), Radar Electro-Optical (REO), and fire control radar. Organic maintenance for these subsystems is not currently planned.

4.2.5.6 Assessment of F-16 Support Posture

The F-16 support systems include a Dynamic Simulation System (DSS) with an Avionics Equipment Bay (AEB) that provides the capability to perform extensive testing of Fire Control Computer (FCC) changes. The interface to the operator via the Head Up Display (HUD) simulation and controls is excellent, and the DSS has been used as an interim pilot trainer. Dynamic test consoles for the stores management system and the HUD will provide unit development and test capability for those systems.

Significant hardware and systems tests can be performed on the DSS/AEB. In addition, changes in the radar system can also be tested in the Radar Engineering Stand (RES) portion of the support facilities. The DEC-10 that is the host computer for the DSS has an effective data base management system that is currently being used as the basis for a configuration management system. Support for the F-16 ECS will be both organic and level-of-effort contractor. While the F-16 FCC is pre-PMRT, in concept the support facility will be capable of providing effective support. The development of the OFP support system for the F-16 is being performed primarily by contract. Modifications to the OFP's and the support system after PMRT is to be performed by a mix of organic and contractor personnel. The OFP's are to be supported by MMECA while the facilities are to be supported by MMETA. Programming support is to be provided by ACDC and contractor.

The F-16 ECS support facility, although not completed, conforms with the AISF concept. Since this facility is not yet operational the full impact of multi-national support needs cannot be assessed. As the F-16 weapon system matures and increases in use by participating nations or through Foreign Military Sales (FMS) the AISF capability will of necessity undergo a corresponding change. Based on planning documents the capability of the AISF to support the requirements is presented in Table 4-4.

4.3 F/RF-4 WEAPON SYSTEM DESCRIPTION

The F/RF-4 is a twin engined, high performance fighter bomber. Its primary mission role is tactical strike and air defense for the F-4E and reconnaissance and electronic countermeasures for the RF-4C.

Both aircraft are undergoing Class V modifications to replace analog computer systems with digital systems. The first modification, commonly referred to as the digital LRU-1 (air combat maneuvering),

Table 4-4. F-16. Support Status

Requirements	Findings/Remarks
ECS Change	Procedures will follow OO-ALC software change process. Change candidates will be subjected to cost estimates, necessity, and benefits criteria. Currently, a fixed level of resources is planned.
Change Analysis and Specifications	AFR 800-14 is being used to establish procedures for accepting, analyzing, and specifying changes. Cost estimates and risk assessments are made organically on each change. Specifications are prepared for each change whether it is done organically or with contractor support.
Engineering Development and Unit Test	Individual stands exist for fire control computer and stores management system, though these are connected by 1553A Bus in the F-16 aircraft. A separate dynamic test control is planned for the Heads Up Display (HUD). Hardware changes affecting the F-16 avionics can be made and tested in the Avionics Equipment Bay (AEB). Radar changes can be developed and unit tested in a radar engineering stand being included as a part of the support facility.
Systems Integration and Test	Software integration and test of changes to the fire control computer can be performed on the dynamic simulation system. Hardware interfaces between the LRU's in the forward section of the F-16 and the FCC will also be tested in the DSS/AEB support facility. Final systems test will utilize a flight test aircraft.
Change Documentation	The ECS documentation for the F-16 will be baseline in phases. This documentation will be done manually.
Certification and Distribution	The certification and distribution will be the responsibility of the system manager once the F-16 is transitioned to OO-ALC.

replaces the analog computer in the APQ-120 fire control radar with a 16K word Westinghouse millicomputer. The second modification, known as ARN-101 (digital modular avionics system), replaces the ASN-46A navigation computer set, the ASN-56 inertial navigation set, and in the F-4E, the ASQ-91 weapons relea e computer set.

4.3.1 F/RF-4 Embedded Computer System

The AN/ARN-101 system, which will be the primary navigation system for the F-4E and RF-4C, employs a central digital computer, (Lear Siegler LS-52, 64K), a signal data converter, a Loran receiver, a digital Inertial Measurement Unit (IMU), and a three axis H-field Loran antenna. On the RF-4C, see Figure 4-12, the AN/ARN-101 interfaces with the AN/APQ-99 Forward Looking Radar (FLR), the AN/ASQ-154 data display set, and related dedicated reconnaissance subsystems. On the F-4E, see Figure 4-13, the AN/ARN-101 interfaces with the AN/APQ Fire Control Radar (FCR), the AN/ASG-22 Lead Computing Optical Sight System (LCOSS), and the Target Identification System Electro-Optical (TISEO) for weapon delivery systems. The operational flight programs in each aircraft include interface with the PAVE TACK system.

The APQ-120 (Digital LRU-1), see Figure 4-14, a one-for-one replacement for the analog LRU-1, operates in five modes; Visual Identification (VI) used for identification and refueling, Long Range Intercept (LRI), Air Combat Maneuver (ACM), Counter Countermeasures (CCM) and search. Figure 4-15 shows a simplified diagram of the F/RF-4 embedded computer system.

4.3.2 F/RF-4 OFP Change Process

The normal OFP update cycle is designed for correction of a number of deficiencies with a new OFP version to be released approximately once each 18 months. OFP changes are to be consolidated for

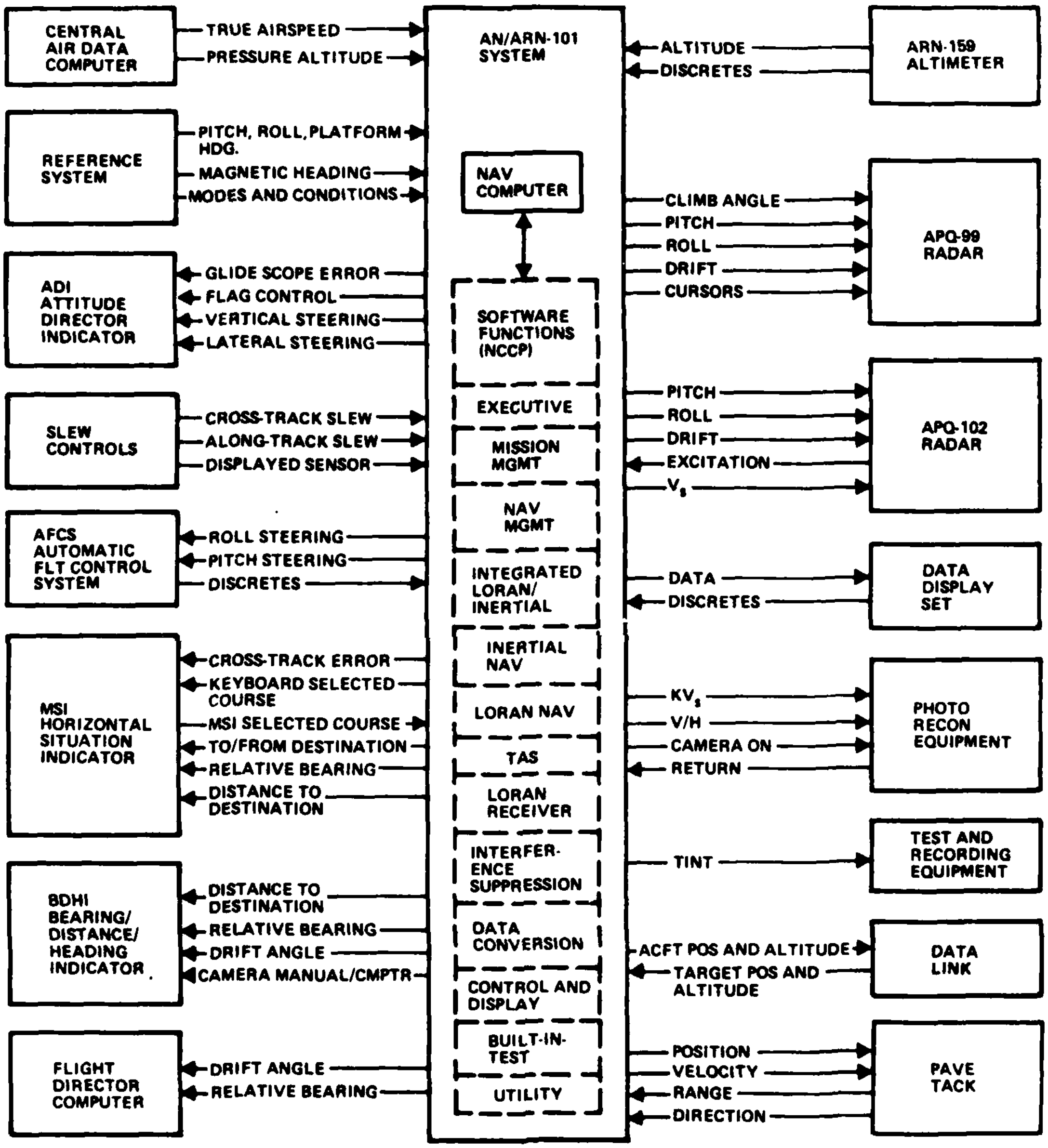


Figure 4-12. RF-4C Interfaces and Systems External to ARN-101

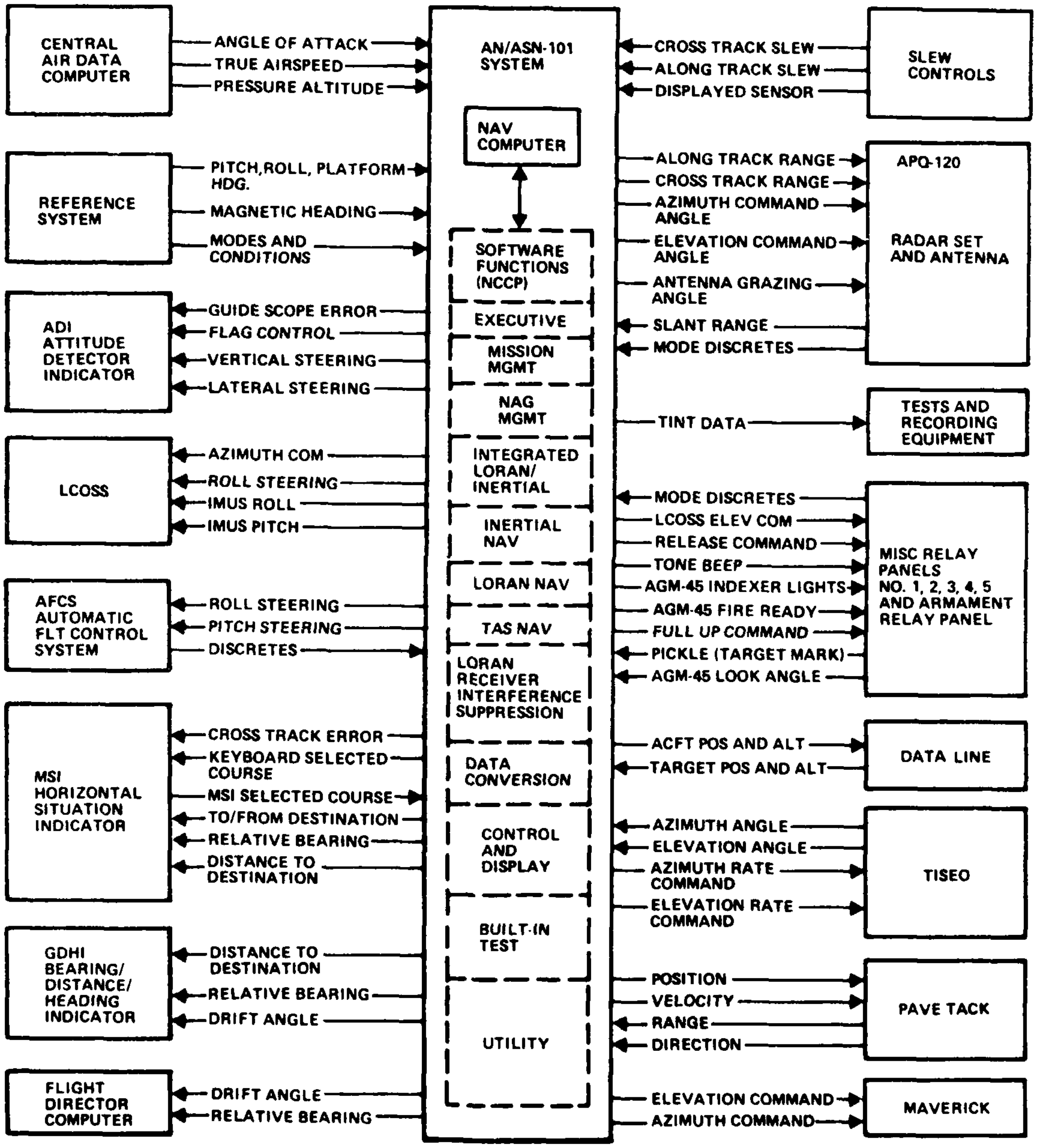


Figure 4-13. F-4E Interfaces and Systems External to the ARN-101

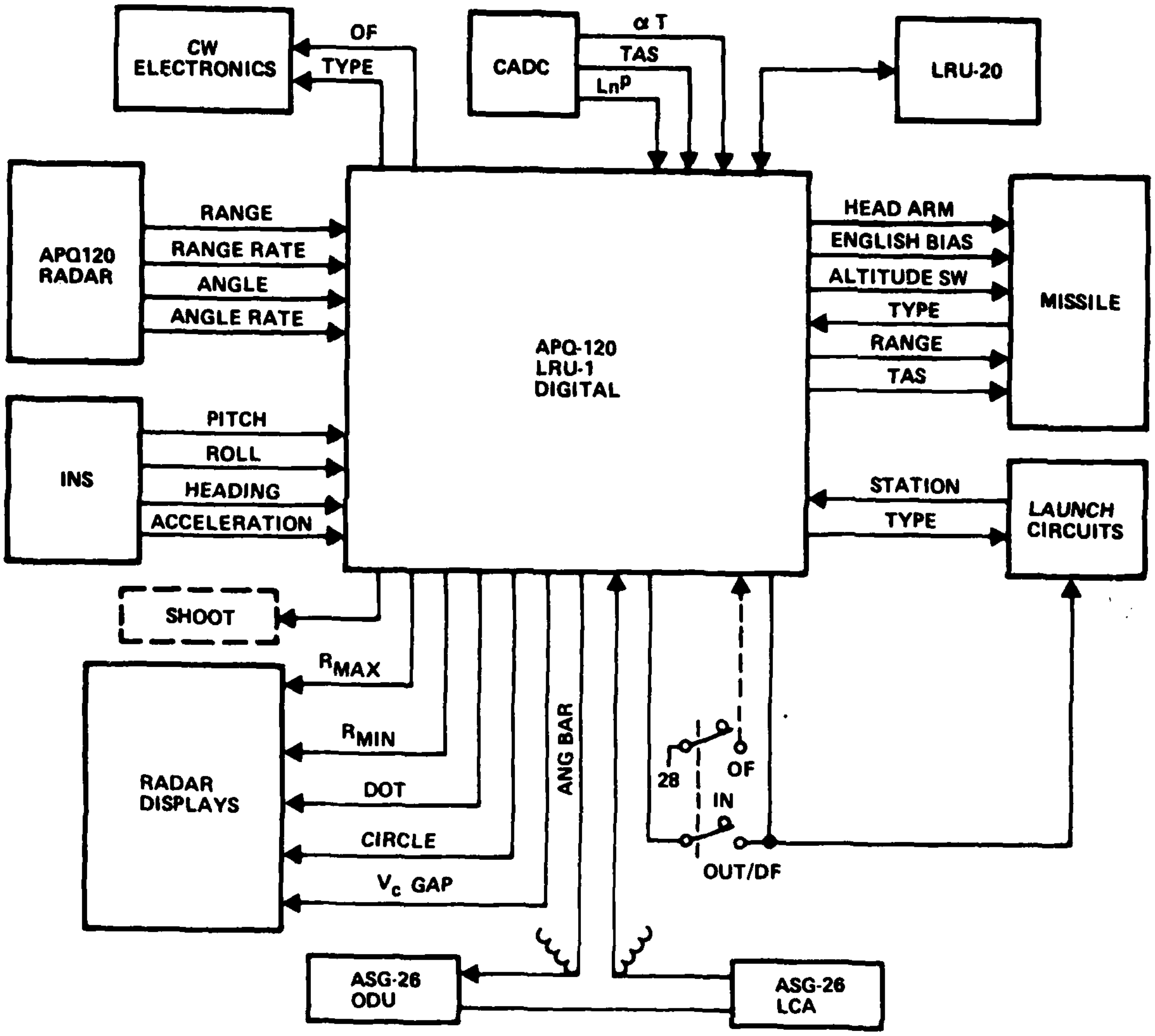


Figure 4-14. Interfaces and Systems External to APQ-120 Digital LRU-1

NAVIGATION COMPUTER (OFP)

OFP FUNCTIONS

GENERIC NAME	F/4E/RF-4C NOMENCLATURE
• NAVIGATION	• INERTIAL NAVIGATION SET
	• LORAN NAVIGATION
	• LCOSS (F-4E ONLY)
	• REFERENCE SYSTEM
	• SLEW CONTROLS
• CONTROLS AND DISPLAYS	• HEADS UP DISPLAY
	• DATA DISPLAY SET (RF-4C ONLY)
• RADAR	• RADAR SET AND ANTENNA (F-4E ONLY)
	• ALTIMETER (RF-4C ONLY)
	• RADAR (RF-4C ONLY)
• WEAPON CONTROL/DELIVERY	• ARMAMENT RELAY PANEL
	• DATA LINK
	• PAVE TACK
	• MAVERICK AND TISEO (F-4E ONLY)
	• PHOTO RECONNAISSANCE EQUIPMENT (RF-4C ONLY)
• FLIGHT CONTROL	• ATTITUDE DIRECTOR INDICATOR
	• AUTOMATIC FLIGHT CONTROL
	• HORIZONTAL SITUATION INDICATOR
	• BEARING DISTANCE READING INDICATOR
	• FLIGHT DIRECTOR
	• CENTRAL AIR DATA
• FLIGHT RECORDING	• TEST AND RECORDING EQUIPMENT
• ENGINES	
• BUILT-IN-TEST	• BUILT-IN-TEST

Figure 4-15. F/RF-4 Embedded Computer System

periodic updates and, when possible, the block update is to be synchronized to hardware updates. The 18 month block update cycle is to be accomplished by overlapping the various development schedules. The envisioned OFP block change cycle is essentially the same as that for the F-16 shown previously in Figure 4-9 and Table 4-3.

4.3.3 F/RF-4 OFP Support Interfaces

The system manager is responsible. OO-ALC organizational interfaces are the same as for the F-16, see paragraph 4.2.3.

4.3.4 F/RF-4 OFP ECS Hardware Support

Hardware support will follow standard AFLC procedure which was previously described for the F-16, see paragraph 4.2.4.

4.3.5 F/RF-4 OFP ECS Software Support

The support facilities for the F-4E and RF-4C OFP's are nearing completion and are colocated in building 1204 at Ogden ALC. Separate dynamic simulation systems (referred to as dynamic simulation area by Ogden personnel) and static test stands are being developed for the LRU-1 (air combat maneuvering) and the AN/ARN-101 (digital modular avionics system). These engineering laboratories which are described in the following paragraphs consist of:

- Off-line computer support
- Dynamic simulation
- Avionics integration
- Instrumented flight test aircraft
- Subsystem test

4.3.5.1 Off-line Computer Support

The off-line computational support required for changing/modifying the F-4E and RF-4C OFP's will be provided by the General Purpose Computer Complex (GPCC). The GPCC consists of an Ogden ALC based IBM 360-65.

4.3.5.2 Dynamic Simulation

Separate dynamic simulation systems are provided for the LRU-1 (air combat maneuvering) and the AN/ARN-101 (digital modular avionic system). Each simulation system equipment configuration consists of simulation host processors, special interface hardware, the actual flight computers with their OFP's, and an operator test station. The major elements of the air combat maneuvering dynamic simulation system is shown in Figure 4-16. The AN/ARN-101 system is shown in Figure 4-17. Figure 4-18 is a simplified version of the combined dynamic simulation systems. Also shown in the figure is the static test stand which is a stand alone element and is discussed in the following paragraph. It is shown here for ease of comparing the AISF elements between the representative support systems.

4.3.5.3 Avionics Integration

Two separate Static Test Stands (STS) are used for control and monitoring of the Air Combat Maneuvering (ACM) and AN/ARN-101 operational flight programs. The STS is used for avionics integration and subsystem testing by providing the capability for data input/output, run/halt control, memory and register accesses, and control functions. The testing is accomplished by halting the computer for data input/output as opposed to dynamically providing environmental simulation. Figures 4-19 and 4-20 show the static test stands for the ACM and AN/ARN-101 operational flight programs.

4.3.5.4 Instrumented Flight Test Aircraft

Ogden ALC plans for use of two test aircraft; an F-4E equipped with AN/ARN-101 ACM and PAVE TACK kits, and an RF-4C equipped with AN/ARN-101. The aircraft are to be assigned to the Specialized (Test) Engineering Branch (MMET) and be instrumented to facilitate testing for system engineering, failure analysis, prototyping and support equipment. The Utah test and training range will be used for the majority of flight tests and data reduction and analysis will be accomplished on the IBM 360-65.

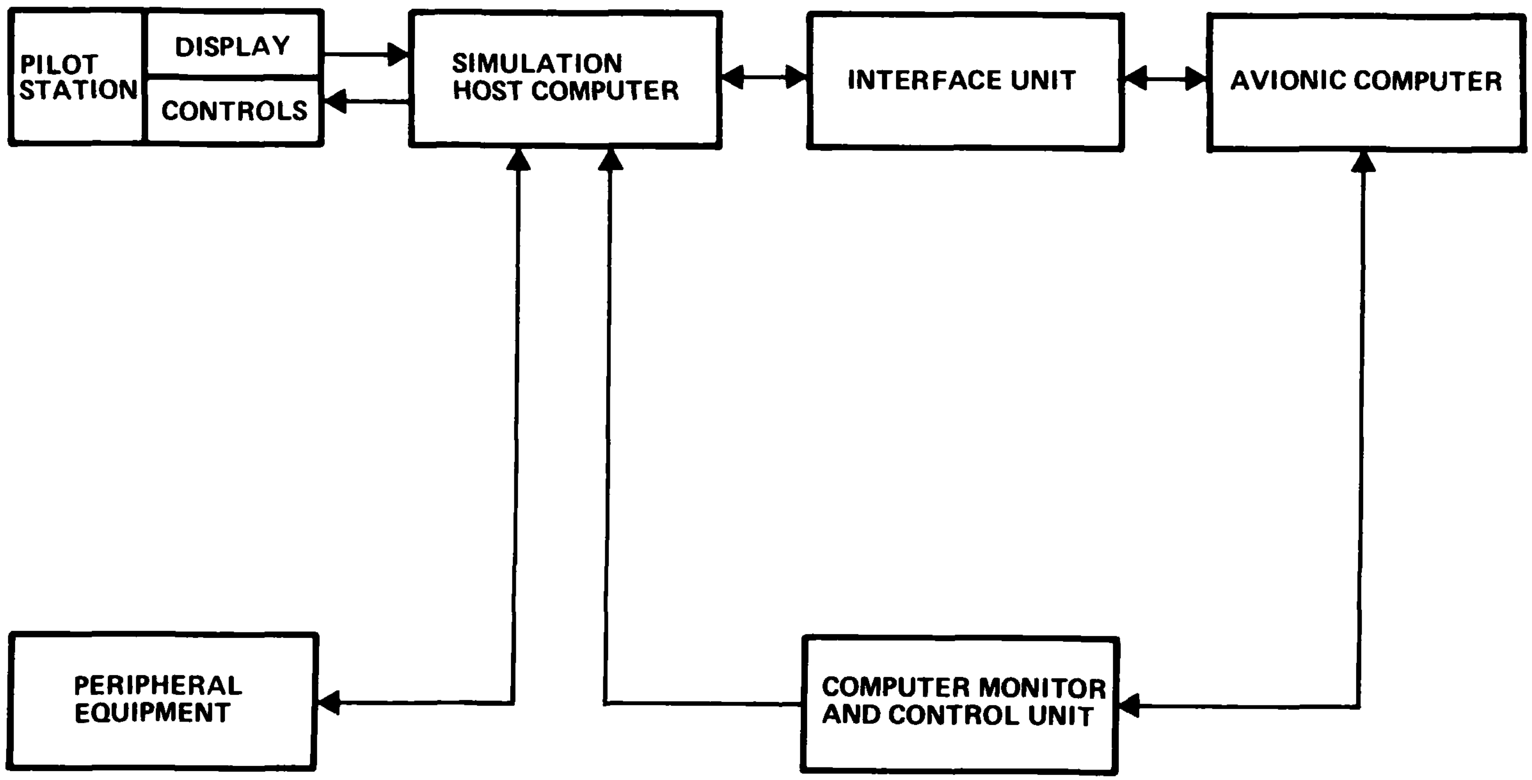


Figure 4-16. ACM Dynamic Simulation Area

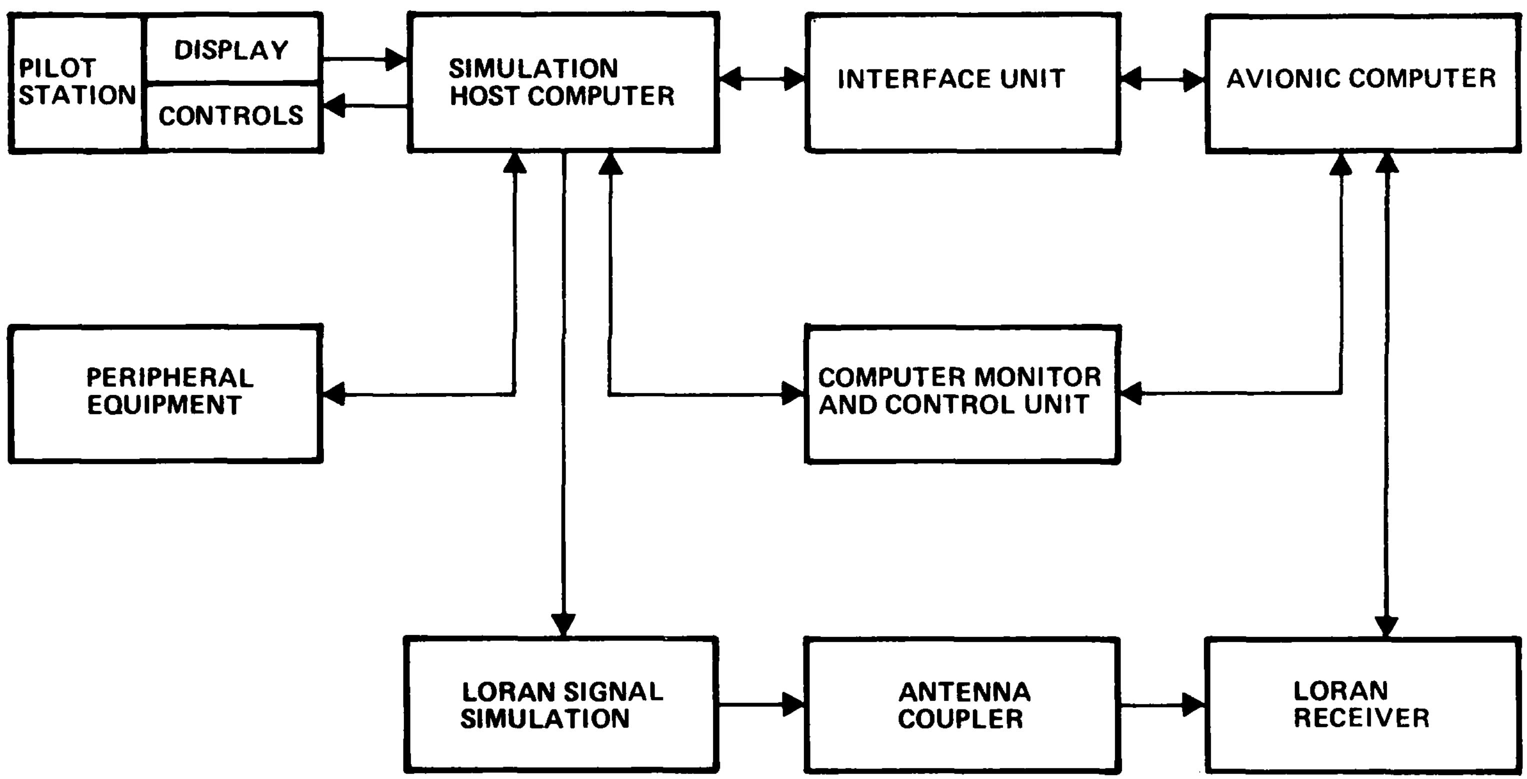


Figure 4-17. ARN-101 Dynamic Simulation Area

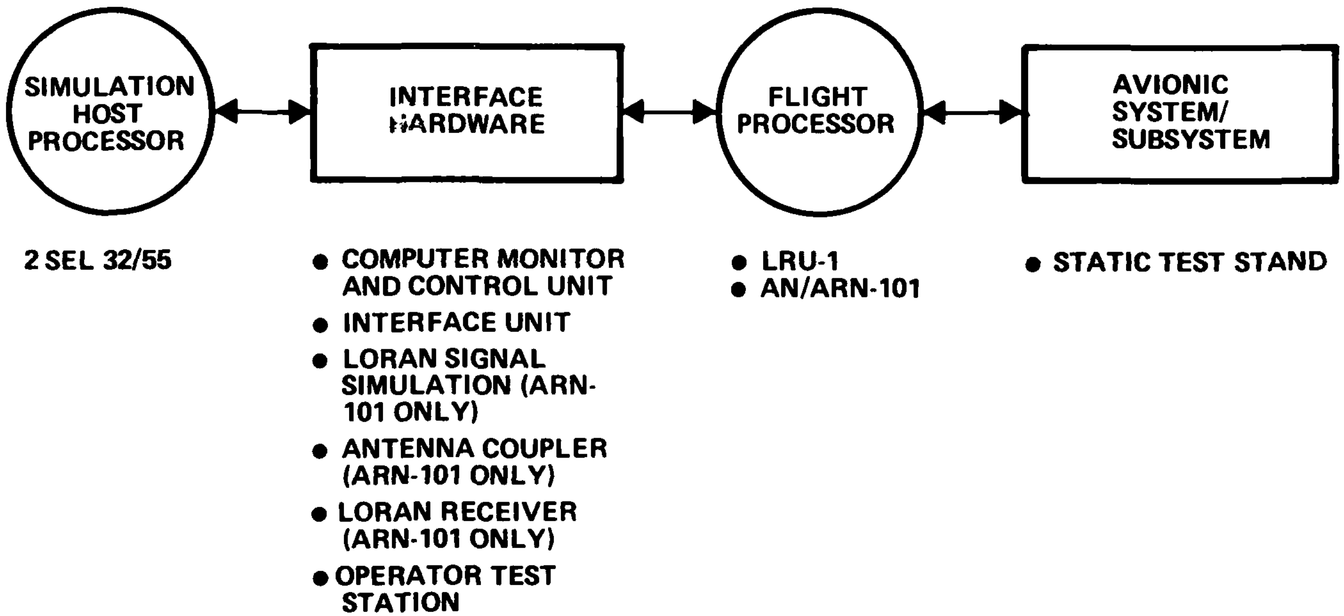


Figure 4-18. F-4E and RF-4C Dynamic Simulation System and Static Test Stand

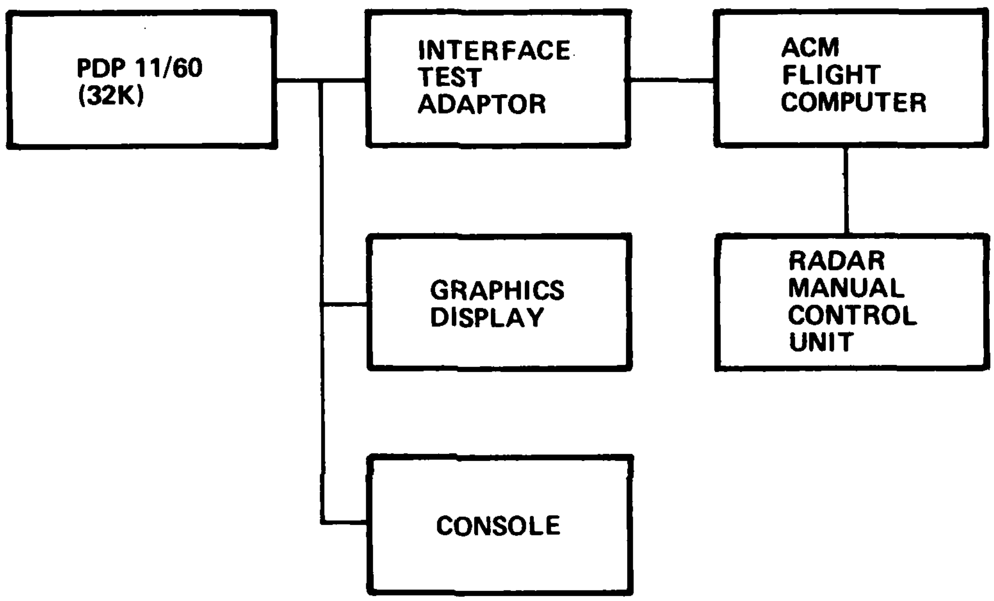


Figure 4-19. LRU-1 ACM Static Test Stand

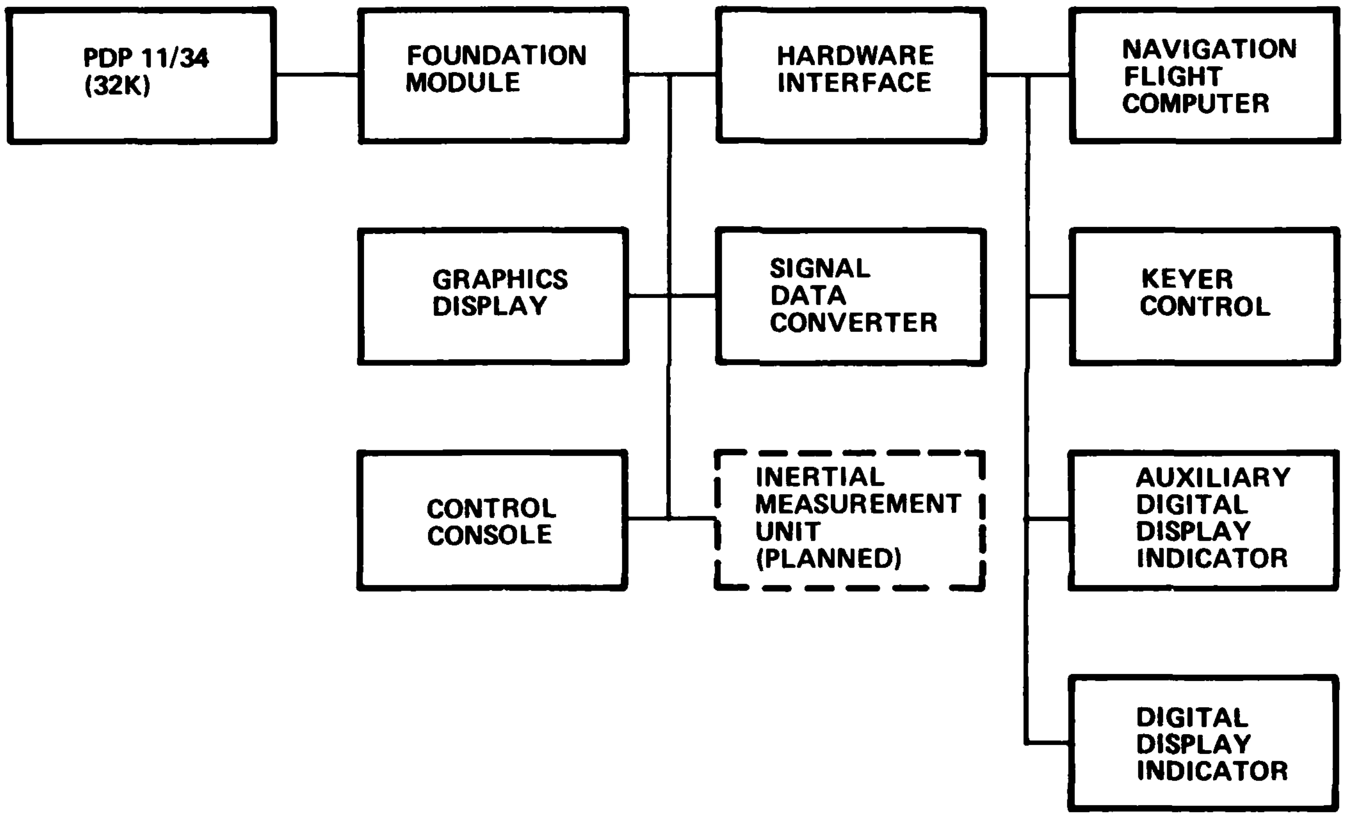


Figure 4-20. AN/ARN-101 Static Test Stand

4.3.5.5 Subsystem Test

Subsystem test will be accomplished on the static test stands. See paragraph 4.3.5.3 (Avionics Integration).

4.3.5.6 Assessment of F/RF-4 Support Posture

The F-4 support systems include individual AISF's to support the ARN-101, PAVE TACK and ACM digital computer, static test stands for the ARN-101 and ACM computers, plus specialized software for all three avionics computers. These tools represent the latest technology for software change and testing. Software changes can proceed from development testing on a static test stand through extensive verification on a dynamic simulation facility for the ARN-101 and ACM computers and on an AISF for the PAVE TACK computer. Hardware-to-software interfaces and system tests involving the hardware must be performed on an F-4 aircraft since a limited set of group B equipment is used in the AISF. This differs from the F-111 where the PAVE TACK/F-111 interface can be tested in an AISF. Automated tools for configuration management will exist for the PAVE TACK at WR-ALC and are being developed for the ARN-101 and ACM at OO-ALC. A word processor is being used for documentation of the ARN-101 and ACM support facilities, while the operational flight programs and technical orders are manually maintained. The development of the AISF's is managed and controlled by government personnel with the support of on site contractor personnel at both ALC's. Experience levels on the AISF's are high for the government managers and the contractor support personnel. Support software that would enhance the analyses of test data from the AISF's and flight tests is limited at OO-ALC, though some development is under way and more is planned. The support software for flight test of the PAVE TACK is currently under way and is based on the F-15 system. Accessibility to off-line processors for development tools has been restricted in the past but is improving for the ARN-101 and ACM.

Support of the AISF's will be a combination of level-of-effort and specialized support. The combination of static test stands and AISF's is designed to provide effective software support for OFP changes for the ARN-101 and ACM. System integration of the F-4, including hardware-to-hardware and hardware-to-software testing for the F-4 will be performed in the flight test aircraft.

The F/RF-4 support facilities do not entirely conform with the AISF concept in that an integration hot bench capability is not currently planned. The use of flight test to accomplish this function is not deemed as capable or cost effective when compared to a ground-based laboratory. The F/RF-4 AISF is scheduled to become operational in 1980 and as operational needs mature it is expected that support requirements very similar to those experienced by the F/FB-111 AISF will dictate a more capable F/RF-4 AISF. Findings/remarks relevant to the planned capability to support the requirements are contained in Table 4-5.

4.4 MINUTEMAN III (WS-133AM) ICBM SYSTEM DESCRIPTION

The Minuteman WS-133AM weapon system description is presented below. The WS-133B weapon system description has been omitted since it is very similar to but simpler than Minuteman III. The Minuteman III weapon system can deliver thermonuclear warheads to pre-selected targets from hardened, dispersed launchers located in the United States. Launch commands originate at hardened, manned Launch Control Facilities (LCF's) and reach distant Launch Facilities (LF's) via a hardened, underground cable system. Launch command messages may also originate from an Airborne Launch Control Center (ALCC). The ground electronics system provides the LCF operational controls and command/status communication links with each LF.

The weapon delivery system is the Minuteman solid propellant LGM30G missile. The guidance control unit of each missile contains four sets of target parameters, each of which controls the trajectories

Table 4-5. F/RF-4 Support Status

Requirements	Findings/Remarks
ECS Change	Procedures are being established to support upcoming modifications to Operational Flight Programs (OFP) for ARN-101 Air Combat Maneuvering (ACM) and PAVE TACK computers. Simulation support facilities are in final stages of development while other tools (e.g., Interpretive Computer Simulation and Static Test Stands) are operational. After PMRT, changes will be negotiated with user against a set of essentially fixed organic resources for OFP modifications and more flexible contractor support. ARN-101 and ACM changes will be made at OO-ALC while PAVE TACK changes will be made at WR-ALC.
Change Analysis and Specification	AFR 800-14 has been used to formulate procedures that will be used for software modifications and as documentation guidelines. Documentation of the ARN-101, ACM and PAVE TACK OFP's, and the majority of support facilities generally follow these regulations but wide variances exist in quality and quantity of documentation. Procedures for change analysis at both ALC's emphasize the Computer Program Configuration Sub-Board (CPCSB) as the approving authority for changes.
Engineering Development and Unit Test	Procedures that have been developed to follow standard development practices. Changes for the ARN-101 and ACM OFP proceed through static, dynamic simulation, and flight tests. A set of standardized tests is planned for the ARN-101 and ACM AISF's to detect unspecified interaction and unexpected results. The PAVE TACK changes will be developed and tested on the PAVE TACK AISF prior to flight testing. Testing of the ARN-101/PAVE TACK interface is currently planned to be performed in the flight test aircraft. The F-111/PAVE TACK interface can be tested in the F-111 AISF prior to flight testing. This includes hardware-to-hardware and systems tests.
Change Documentation	ECS documentation will be baselined at PMRT. Support system documentation will be baselined at completion of basic system. Documentation for OFP's, technical orders, and support systems is being performed by contractors and organic personnel. The documentation is primarily manual.
Certification and Distribution	The system manager will certify and approve revised programs for all three avionics systems.

of as many as three warheads. A specific target set is designated for use prior to launch. A launch can occur a few seconds after the receipt of the launch command or be delayed for several hours.

The basic squadron configuration consists of 50 unmanned missile LF's and five manned LCF's. Automatic LF status reports and LCF self-checks inform the LCF status console operator of equipment malfunctions by means of visual and audible alarms. The LCF operator relays fault indications to the maintenance control center at the strategic missile support base where corrective actions are directed.

The primary mission of the ICBM system is to defer acts of foreign aggression. To accomplish this mission, the ICBM system is designed to survive an act of aggression by a foreign power and still be able to function in a post-attack environment.

Minuteman is currently deployed in four versions, two each for Minuteman II and Minuteman III. While each version is slightly different in the ECS systems, incorporated they are all the same in basic functional requirements and are managed the same. While MX and Cruise will no doubt be different, the basic ECS management requirements outlined here for Minuteman will apply.

4.4.1 Minuteman III Embedded Computer System

The version of Minuteman III specified as WS-133-AM contains five embedded computer systems and one general purpose automated data processing system that provides data for the operational system. These systems are described in Sections 4.4.1.1 through 4.4.1.5. Table 4-6 shows the WS-133-AM equipment identification.

4.4.1.1 Airborne ECS

The airborne ECS is based on the Autonetics D-37D serial computer. The software is comprised of two separately configured computer programs, the first of these programs is the Operational Ground Program (OGP). This program performs the functions of command and control, establishment of the inertial reference, and fault monitoring and reporting. While this program executes only while the missile is in the launcher, it could be categorized as an operational flight program.

Table 4-6. ICBM (WS-133-AM) Equipment Identification

Computer	Where Used	Software
IBM 360	HQ SAC	MOTP, STSS, EPP
WSC	LCF	MOTP, EPP, OEP
DPU	ALCC	DPU Operational/Daily Exercise Program
D37-D	Airborne	OFP, OGP
D37-C	Command CIV at HQ SAC	
D37-D	SMSB CIV	CIV (E)

The operational flight program performs the functions of navigation and flight control. This program executes only after the OGP has satisfied the requirements of flight preparation, launch command validation, and launch. Once control is transferred to the flight program it never returns to the ground program.

4.4.1.2 Command and Control ECS

The command and control ECS is based on a Univac special purpose computer identified as the Weapon System Controller (WSC) that resides in the Launch Control Center (LCC) and interfaces with the operator on one side and the weapon system on the other. The software set consists of the Operational Executive Program (OEP), the Target Constants Generation (TCG) program and the Execution Plan Program (EPP).

The OEP performs command generation and transmission functions under operator manual control as well as automatic status interogation and monitoring functions in real time. It also provides service routines for the TCG and EPP to operate in a background mode.

The TCG program, under control of the OEP, translates target coordinate information into steering and control constants that will be used by the airborne computer to fly to a specific target. This program executes in a variable area of computer memory in a background mode. It normally resides with the EPP and their respective data bases on an auxiliary bulk store memory device adjacent to the WSC.

The EPP generates a series of launch delay and target selection options for use by the OGP in establishing preplanned war execution options. The program operates in the background under control of the OEP in the same resident memory area as the TCG program.

4.4.1.3 Secure Code Processing ECS

Two ECS's are provided in the system to prepare secure code material for use by the weapon system. These codes are used to validate legal orders for launching the Minuteman force. The ECS systems are identified as the Command Code Inserter Verifier (CCIV) that uses the Autonetics D-37C computer to process the code material for the entire force and is located at Strategic Air Command Headquarters. The Code Inserter Verifier (CIV) using the D-37D and WSC computers distributes specific code material to individual LCF's and Launch Facilities (LF's) as well as formatting unique launch point data for each LF. A CIV is located at each Strategic Missile Support Base (SMSB) that is geographically located with each missile wing.

4.4.1.4 Airborne Launch Control Center ECS

The Airborne Launch Control Center (ALCC) is an ECS that provides a backup launch capability. The Data Processing Unit (DPU) executes software that provides test and secure enable and launch messages to Minuteman LF's.

4.4.1.5 SAC Targeting Support System ADPE

The SAC Targeting Support Software (STSS) executes on an IBM 360 system at SAC headquarters and provides the data bases that are used at the LCF to generate target constants by the TCG and execution plan options by the EPP.

4.4.2 Nuclear Safety Support Criteria

The total number of embedded computer systems that control nuclear weapons is small, but due to the seriousness of a nuclear incident or accident, too much emphasis cannot be placed on the need for stringent support. Only two operational systems fall into this category current with two new systems in development. The Minuteman ICBM system in four versions and the Titan II ICBM system are currently operational while ICBM MX and air launch and ground launch cruise missiles are under development.

Embedded computer systems that have a first or second level interface to a nuclear weapon as defined in AFR 122-9 are few in number, but it is readily apparent that their sensitivity is critical. This type of system over the past fifteen years has caused great concern to the safety community and has resulted in implementation of policy and programs that minimize the risk of an embedded computer system contributing to a nuclear incident or accident. These policies are well implemented in ballistic missile system acquisitions in the Air Force Systems Command and are carried over to the Air Force Logistics Command at OO-ALC for the Minuteman ICBM. The following definitions are provided to form a common basis of understanding for discussion of nuclear weapon system control ECS support:

- Nuclear weapon control software - programs that execute in embedded computers which have a first or second level interface with a nuclear weapon.

- First level interface - any software used by automata which control critical function of a nuclear weapon.

- Second level interface - any software used by automata which respond to or transmit information to automata having a first level interface.

- Automata - class of sequential machines which, by alternation of internal state, are capable of performing logical, computational, or repetitive routines. Examples are automatic processors, microprocessors, computers, decoders, controllers, and where specifically designated, their associated peripheral equipment.

Of the four NWSC systems that are the AFLC support responsibility, the system described in this section is representative of the category in its present state. The intent of this section is to describe a sample weapon system and the ECS support systems. The weapon system chosen is the Minuteman III version of the WS-133-AM ICBM system. The support system consists of the aggregate of test facilities at OO-ALC generally identified as the Hill engineering test facility.

4.4.3 Minuteman Software Change Process and Interface

The weapon system is made up of two basic parts: the airborne system consisting of the missile, and the ground system consisting of the missile launch facility and the launch control facility. Each of these segments has operational software, which is supported under contract, as an integral part and for that reason procedures are required to maintain a firm configuration baseline. The software change process is shown in Table 4-7.

A Minuteman Operational Software Working Group (MOSWG) is organized to review all activities involved in the maintenance and update of Minuteman operational tapes/programs as well as the weapon systems software associated technical orders and supporting documentation. The group ensures that all changes to existing operational software are compatible with other weapon system software, overwrite software, trainers, depot test equipment, etc., and that the weapon system mission requirements are maintained. The MOSWG can only recommend changes to the operational software to the OO-ALC/CPCSB or SAC/CCB.

Table 4-7. Minuteman Software Change Process

Phase/Support Requirement	Engineering Activity and Primary Output/ Control Documentation
Deficiency Report/Change Procedures	Submittal of change requests. Most frequently, changes originate through deficiency reports submitted in accordance with AFR 74-6, AFLCR 800-21, and T.O. 0035D-54. All change activity is controlled through the Material Improvement Program (MIP) and tracked through the G026 reporting system. The deficiency report categories which apply are: ● Category I MDR - report of an emergency condition which presents, or has the clear potential to present an unacceptable safety, operational, or maintenance hazard. ● Category II MDR - deficiencies which are related to the errors generated in design and production or changes that could upgrade the operation. New capability programs will be generated in accordance with the procedures of AFR 57-1.
Change Evaluation and Classification Assessment	Deficiencies which are identified in Minuteman operational software managed by OO-ALC will be evaluated, assessed, and processed in accordance with the procedures outlined in the O/SCMP and in AFLCR 66-15, OOALCR 66-3 and 800-3, and DMMOI 81-3. Briefly, the process will be as follows: ● Identification of deficiency reported to OO-ALC/MMMS by user, contractor, or OO-ALC agencies. ● OO-ALC/MMMS determines the action point, initiates a MIP, and forwards the MDR to MMGR. ● OO-ALC/MMGR evaluates the MIP, responds to the originator within the established time schedule as defined in the aforementioned publications, updates MIP actions with MMMS as required, and requests MMEC support. ● OO-ALC/MMEC evaluates the MIP, prepares a CEP or EPR as required; evaluates the ECP; prepares the AFLC Form 75, the OO-ALC Form 446, and a CEP; and forwards the package to MMGR.

Table 4-7. Minuteman Software Change Process (Continued)

Phase/Support Requirement	Engineering Activity and Primary Output/ Control Documentation
Change Evaluation and Classification Assessment (Concluded)	• OO-ALC/MMGR then prepares AFLC Forms 75 and 873, a staff study, Environmental Impact Statement (AFR 19-2), and budgetary cost information. These items are consolidated with the MMEC package and retained for presentation to the MOSWG. The ICWG is also provided documentation for interface evaluation. • The ICWG evaluates the change for weapon system interfaces impact and provides the CPCSB with a recommendation for approval or disapproval. • The MOSWG reviews the proposed change and provides recommendations to the CPCSB. • The CPCSB approves or disapproves the change for forwarding to the AFLC/CCB. Deficiencies which are identified in Minuteman operational software managed by SAC are evaluated, assessed, and processed in accordance with SAC established procedures and reviewed by the MOSWG and CPCSB as stated in the O/SCMP.
Emergency Change Procedures	Configuration changes which are of an emergency nature are processed within the time frames established in MIL-STD 480 and T.O. 00-35D-54.
Coordination	• Coordination with change originator. Coordination on Category I MDR's is in accordance with T.O. 0035D-54, Section VII. • Coordination on Category II MDR's is in accordance with T.O. 00-35D-54, Section VIII. • Coordination with user. The SM apprises Hq SAC of acknowledgement and interim or final responses to all Category I/III MDRS, ECP's, letters, etc., which affect Minuteman operational software. If an MDR is submitted in error or if additional information is required, the corrective action is negotiated between SAC and the SM.

Table 4-7. Minuteman Software Change Process (Continued)

Phase/Support Requirement	Engineering Activity and Primary Output/ Control Documentation
Test of Change Design	• Development testing. Development testing is accomplished when a particular routine has been compiled, debugged, and checked out well enough to allow successful execution. Emphasis is placed on exercising every instruction, providing accuracy of computations, showing repeatability of results, testing upper, lower and nominal ranges of data values, testing error conditions and verifying timing, sizing, interfaces and data handling characteristics on a routine-by-routine basis. During this phase documentation, as specified by the government, is maintained and includes such information as requirements interfaces, preliminary design, detailed design, test plans, test procedures, and test results. • Qualification testing. Qualification testing is the formal testing that occurs by the developing contractor under government approved test plans. All qualification testing is conducted using operational software and computer hardware, that is, the identical components used in support of the system mission. Errors and other problems discovered during this testing and testing at other facilities, are referred back to the contract OPR for evaluation and direction for correction as required. A complete qualification test report is prepared by the developer to be used as the basis for the functional configuration audit. • Integration testing. Integration testing is formal testing conducted by the integrating agency in parallel with qualification testing. The integrating agency is designated and an integration test plan is prepared as specified in the contract. Emphasis during integration testing is placed on validating that the requirements imposed by the higher level specification are met. The main purpose of validation testing is to demonstrate that actual performance meets required performance with the software product functioning in as near an operational environment as practical. A complete integration test report is prepared by the integration agency prior to release of the program to the field. Test reports are reviewed and problems resolved by OO-ALC/MMECM.

Table 4-7. Minuteman Software Change Process (Continued)

Phase/Support Requirement	Engineering Activity and Primary Output/ Control Documentation
Test of Change Design (Concluded)	• Nuclear Safety Cross-Check Analysis (NSCCA). The nuclear safety cross-check analysis performed on Minuteman operational software is one of the positive measures implemented by the Air Force to fulfill the DOD nuclear safety standards. The NSCCA provides assurance that the software as designed, coded, and implemented cannot contribute to accidental, unauthorized, or inadvertent activation of critical nuclear weapon system functions. This testing will be performed by an independent contractor appointed by OO-ALC/MMECM. A full NSCCA report is prepared and reviewed prior to NWSSG certification for operational use of the computer program. NSCCA may be performed in parallel to a great extent with qualification and integration testing. • Operational Test and Evaluation (OT&E). Testing in an operational environment is accomplished to assure proper operation of a new or modified program. Typical OT&E procedures utilize a larger number of computers and expanded test conditions than are found in the aforementioned engineering tests. SAC is responsible for providing OT&E requirements to OO-ALC/MMECM for incorporation into the contract.
Documentation and TCTO Generation	• Documentation. The data items are specified and generally consist of the following: • Computer programs, data, and printouts • Computer program development plan • Interface control drawings • Baseline identification specifications • Users manual • Computer programming manual • Catalog and glossary of computer programs and programming documentation • Minutes of formal reviews and audits • Configuration management plan

Table 4-7. Minuteman Software Change Process (Continued)

Phase/Support Requirement	Engineering Activity and Primary Output/ Control Documentation
Documentation and TCTO Generation (Concluded)	• Version description documents • Configuration index • Change status report • Specification change notice • Engineering change proposal • Test plans, procedures and reports • TCTO Generation. All OO-ALC managed Minuteman operational software changes/modifications are announced in a separate TCTO. Each TCTO is assigned a degree of urgency at the time of CPCSB approval as appropriate. Three designations of urgency are authorized: immediate action, urgent action, and routine action. The AFLC Form 75 will serve as the official record of approval of Minuteman operational software CPCI changes. It is included in the TCTO package with the AFLC Forms 873 and 875, and TCTO draft by the MMGR action point to reflect the authorization of the TCTO by the appropriate approval authority. This package will be prepared and processed by the MMGR action point after CPCSB/AFLC/USAF approval and routed through OSHA, Missile Safety, MMGP, and MMEC to MMED for Minuteman operational software changes. (Refer to AFLCM 66-14 for AFLC Forms 873 and 875 preparation.) The TCTO's used to announce changes to Minuteman operational software will be funded under appropriation 3400, EEIC 594.

Table 4-7. Minuteman Software Change Process (Concluded)

Phase/Support Requirement	Engineering Activity and Primary Output/ Control Documentation
Reproduction and Distribution of Magnetic Tapes and TCTO's	• Hq SAC (DOMC) is responsible for reproducing all Minuteman operational program tapes using the DNS certified MYDAC/DUPCOM computer program and will assure NSCCA's are performed on all tapes as required by the NWSSG. The serialization of reproduced and/or replacement copies of program tapes are the responsibility of SAC as directed in the TCTO. Serialization of replacement copies for unserviceable or damaged tapes is the same as the initial TCTO. • OO-ALC/MMED assures sufficient copies of the TCTO are provided to Hq SAC for distribution to units with the tapes. Hq SAC (DOMC) is responsible for distribution and accountability for SAC and SAC produced copies of the tapes and TCTO's which are provided to the units.
Implementation	• Implementation of approved changes is by means of released TCTO's and associated kits.

All Minuteman operational software changes will be processed through the CPCSB. The CPCSB will be responsible for final engineering approval of all changes to operational software and effects on equipment and related computer programs/systems within the Minuteman weapon system and will also be responsible for final approval of changes, costs, and testing for which OO-ALC has primary management responsibility. The Strategic Air Command Configuration Control Board (SAC/CCB) is responsible for final approval, costs, testing, changes to system documentation, and effects on equipment and related computer programs/systems for which SAC has primary management responsibility.

4.4.4 Minuteman II/III ECS Support System

An extensive set of support equipment exists at OO-ALC under the name of the Hill Engineering Test Facility (HETF). This facility, used to evaluate system level problems, provides the capability to test all of the weapon systems ground functions in a near real environment. While actual system hardware/software is used in limited numbers, command and control simulators are used to provide operational conditions.

The HETF consists of two structural launchers, one each of the WS-133-AM and WS-133-B configurations. Each LF is supported by a compatible LCF, in an above ground configuration and a squadron data simulator. The facility is augmented by several guidance and control facilities designed for software qualification testing that can be electrically integrated into the HETF as simulated launch facilities.

While all Minuteman operational software is developed under contract to specific qualified contractors, the HETF provides means for system and subsystem problem evaluation as well as integration and qualification testing support.

Three basic test facilities exist at Hill AFB for Minuteman system testing. Each facility can be operated in several configurations which include varying amounts of real and simulated Minuteman equipment. The test facilities will be used to support operational software system testing and field problem isolation and resolution. These facilities are described on the following pages.

4.4.4.1 Hill Engineering Test Facility I

The Hill Engineering Test Facility I (HETF I) is configured to provide a total test bed for the Wing III and V systems. The HETF I consists of the following hardware, software, and test elements:

- Real LF and LCF equipment
- Electronic LF
- Electronic LCF
- Squadron data simulator
- Operational software
  - MOTP 19215
  - OEP 19214
  - EPP 19211
  - OGP 19240
  - OFP 19243
- Instrumentation system
- SETS

4.4.4.2 Hill Engineering Test Facility II

The Hill Engineering Test Facility II (HETF II) is configured to provide a total test bed for the Wing VI systems. The HETF II consists of the following hardware, software, and test elements:

- Real LF and LCF equipment
- Electronic LF
- Electronic LCF
- Squadron data simulator
- Operational Software
  - MOTP 19215 (shared)
  - OEP 1921

- EPP 19211 (shared)
- OGP 19241
- OFP 29243 (shared)

- Instrumentation system
- SETS

4.4.4.3 <u>Electronic Test Facility</u>

The Electronic Test Facility (ETF) is configured to provide electrical/electronic test bed for the Minuteman II Wing, I, II, IV, and ERCS force mod systems. The ETF consists of the following hardware, software, and test elements:

- LF and LCF electronic/electrical systems
- NS-17 guidance system
- Squadron data simulator
- Operational software
  - OEP 19200
  - OGP 19236
  - OFP 13001
- Instrumentation system

4.4.5 <u>Minuteman Test and Analysis Tools/Sites</u>

This section describes the analysis and test tools presently available at OO-ALC. These facilities include several special purpose test laboratories and two general purpose computing facilities. The special purpose test facilities generally contain operational Minuteman equipment interfaced with digital computers programmed to provide a simulated operational environment. The general purpose facilities include an IBM 360 computer and CDC CYBER 73 computer. These facilities provide some general support functions such as plot programs, text editors, and debug programs, as well as providing facilities for executing simulation programs.

4.4.5.1 IBM 360 Support Software

Several Minuteman support software programs execute on the Hill Air Force Base (HAFB) IBM 360.

- D37C Assembler
- D37D Assembler
- IBM 360 O/S - the HAFB IBM 360 O/S provides a FORTRAN compiler and program execution monitor with sufficient debug capabilities to support program development.
- Missile flight simulation, CI AK48 - the Missile Flight Simulation (MFS) provides a closed loop simulation of the Minuteman II flight. Executing on the IBM 360, the MFS contains an ICS simulation of the D37C computer and a flight dynamics simulation. The D37C simulation does not simulate the execution of all D37C instructions.
- SAC Targeting Support Software (STSS) - the STSS-400/600 was designed to provide SAC with the capability to assemble, load, and simulate the execution of the WSC MOTP and EPP programs. The WSC simulation simulates only those instructions executed by the MOTP or EPP.

4.4.5.2 Total Integrated System Capability

The Minuteman II Total Integrated System Capability (TISC) employs a D37C, two NOVA computers, and the following peripherals:

- Operator interface (keyboard)
- Interchangeable disk memories
- Paper tape reader
- Printer
- Two CRT displays
- Calcomp plotter

TISC provides an execution monitor and controller for D37C execution. This is accomplished through a modification of the interconnection between the D37C Central Processing Unit (CPU) and its memory disk. A section

of one of the NOVA memories is substituted for the D37C disk memory. This memory can then be presented to the D37C CPU to be operated on properly, but not with the D37C timing constraints, since the D37C disk is effectively removed. The second NOVA is used to simulate either the missile dynamics for flight simulations or the IMU for ground simulations. Some ground functions are not simulated. TISC provides instruction level diagnostics, trace, timing, save/restart, and other ICS-type capabilities.

4.4.5.3 Guidance and Control Test Sites

Three Guidance and Control (G&C) test sites are available at Hill AFB. These sites correspond to the basic weapon system configurations used with Minuteman II and III missiles. Each site contains a Missile Guidance Set (MGS) and associated ground equipment, as well as the Communications and Processing Systems (CAPS).

Each test site is equipped with breakout boxes which allow for alternating or monitoring all hardware signal transmissions. CAPS provides both software diagnostic and simulation features. CAPS has the capability to monitor and present to the analyst the contents of selected D37 memory locations. In addition, CAPS has the capability of keying its responses to the execution of specific locations, the contents of a location attaining a specific value, or on time.

CAPS can provide a squadron message traffic simulation. Any of the G&C test sites can be connected to the Electronics Test Facility (ETF) to provide additional realism in simulating squadron data flow.

- G&C test site one - contains an NS-17 MGS, flight control hardware, including cables, CSD, WS-133-AM LF OGE, and a CAPS configured to simulate both a WS-133-AM LCF and associate squadron message traffic.
- G&C test site two - contains either an NS-17 or an NS-20 MGS, either Minuteman II or Minuteman III flight control hardware, including cables, CSD, WS-133-AM CDB LF OGE, and a CAPS configured to simulate both a WS-133-AM CDB LCF and associated squadron message traffic.

- G&C test site three - contains an NS-20 MGS, Minuteman III flight control hardware, including cables, CSD, WS-133B LF OGE, and a CAPS configured to simulate both a WS-133B CDB LCF and associated squadron message traffic.

4.4.5.4 Squadron Test Facilities

Three Squadron Data Simulators (SDS) at Hill AFB provide the capability to interface real LCF and LF hardware with a system that simulates the remainder of the squadron facilities. The squadron simulation function uses a digital computer with disk storage and a line printer. Squadron message traffic can be printed in real time. The capability to insert faulty message traffic also exists.

In addition to the SDS, two other types of test facilities are presented here. These are launch control facility processor test stations and software evaluation and test systems.

- Electronic Test Facility SDS - provides the squadron simulation for Minuteman II (non-ILCS) and ERCS missile systems. This HE configured SDS will also simulate G missile systems.

- Hill Engineering Test Facility I SDS - provides the squadron simulation for the Minuteman III Wing III and V missile systems. This GIP configured SDS will also simulate F missile systems.

- Hill Engineering Test Facility II SDS - provides the squadron simulation for the Minuteman III Wing VI systems.

- Wing III/V Launch Control Facility Processor/Test Station - an LCF simulator/monitor used to test LCFP/WSC hardware and software in an on-line (in conjunction with HETF I) or off-line (stand alone) environment. The LCFP/TS operates with the WSC/MCG, and SDU and simulates nominal and perturbed LCF equipment operation. Automated test scenarios can be generated off-line and then executed. Outputs made by the WSC to the simulated equipment are displayed by the LCFP/TS. The LCFP/TS can also be used to modify WSC software programs.

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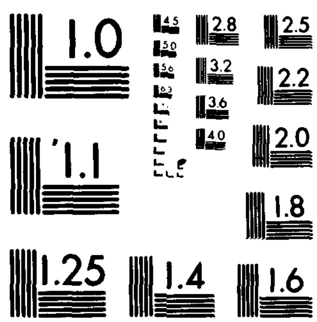

MICROCOPY RESOLUTION TEST CHART

- Wing VI Launch Control Facility Processor/Test Station - provides capabilities for the Wing VI LCFP.

- Wing III/V Software Evaluation and Test System (SETS) - a high speed digital data acquisition and control system used to test operational LCFP/WSC hardware and software. SETS selectively acquires data from weapon system interfaces in a real time, non-interfering manner. Data are acquired selectively by two hardware interface preprocessors which are programmable by the test operator. Acquired data are processed on-line by software in the central data acquisition unit and stored for for reduction on magnetic disk.

- Wing VI Software Evaluation and Test System - provides the capabilities for the Wing VI LCFP. SETS can also be used to modify (patch) any WSC/MCG software programs.

4.4.5.5 Assessment of Minuteman II/III Support Posture

A thorough and disciplined approach to support of Minuteman II/III operational software is being developed and pursued at OO-ALC. Documentation, plans, and procedures are detailed; extensive and effective test tools and facilities are used. Air Force regulations and MIL-STDS are applied in an aggressive manner. Coordination and interfaces are closely monitored. Skill levels vary but are generally high at both government and contractor facilities. The user is actively involved. The independently developed Minuteman II/III ECS support concept and the resulting support posture have evolved over a long period of time with PMRT occurring long after the systems were operational. Also due to these systems' role in the nation's defense posture and the user (Strategic Air Command) being designated a specified command responsive to the Joint Chiefs of Staff (JCS), the support has been afforded commensurate management attention. This is not to say that no problems exist, but rather to say that due to its high visibility a degree of aggressiveness, thoroughness, and adherence to established procedure exists that is not as apparent at other support facilities. Comments related to the support requirements are presented in Table 4-8.

Table 4-8. Minuteman II/III Support Status

Requirement	Findings/Remarks
ECS Change	Detailed procedures established over a period of time were tailored for transition from SAMSO (now BMO) to OO-ALC.
Change Analysis and Specification	Activities and procedures are detailed and formal with extensive user involvement. Air Force regulations and MIL-STD's are fully invoked. Extensive use of tools and analysis aids.
Engineering Development and Unit Test	Primarily performed under contract to original development contractor. Standard acquisition and development process is used.
System Integration and Test	Accomplished primarily at Hill Engineering Test Facility with detailed plans and procedures. Widely coordinated and tightly controlled interfaces.
Change Documentation	Documentation is thorough and complete with responsibilities clearly defined.
Certification and Distribution	Accomplished under tight control with reproduction and distribution responsibilities clearly defined.
Nuclear Safety	Procedures essentially carried forward at PMRT to OO-ALC NSCCA performed by independent contractor. Procedures are detailed and closely adherred to.

5. ASSESSMENT OF OFP SUPPORT POSTURE

The OFP support concept for aircraft ECS has evolved since the early 1970's. It is well understood within the engineering divisions that are either operating or establishing support facilities. Implementation of the concept, however, tends to vary with the particular location of the support facility. This is attributed primarily to circumstance at the time of the weapon system acquisition or modification in terms of available funds/source of funds and the level and number of skilled personnel available at the particular location. Another important factor has been the relative immaturity of the software support discipline with attendant lack of widely recognized/acknowledged requirements, established policy, guidance and procedure, and experience as well as a lack of data in government or industry upon which to base decisions.

Substantial progress has been made and support is being provided but there are differences in the support approach. For example, the A-7D is currently supported at China Lake NAS through a joint service agreement. On site engineering support is provided at China Lake with management at Oklahoma City ALC. The Air Force also provides test aircraft and funds to the U.S. Navy on a proportional basis. Engineering support for the F-106 OFP is provided primarily by contract. San Antonio ALC manages the effort and provides test equipment, test aircraft and limited engineering support.

The F/FB-111 is supported at Sacramento ALC and is the first and currently the only Air Force operational aircraft OFP support facility. Support facilities for other major aircraft weapon systems, such as the F/RF-4, F-15, and F-16, are in various stages of development to meet anticipated support requirements. These facilities, for the most part, are patterned after the F/FB-111 OFP support facility except for a planned reduced reliance on continuing contractor support. Consequently their capability, when operational, is expected to be equivalent to the F/FB-111 facilities except for the F/RF-4 facilities, which, if completed as planned, will not include a full integration hot bench capability.

Support facilities for missile systems are currently limited to the Minuteman II and III. Support facilities for SRAM are in the planning phase. The operational software changes/updates for these systems are accomplished by the original development contractor with system engineering and integration and test being accomplished by a combination of government and contractor personnel primarily at OO-ALC. The effort is managed by OO-ALC and the test facilities and stations are collectively referred to as the Hill Engineering Test Facility.

Support requirements for the OFP category date back to the A-7D and F/FB-111 facility development time frame. However, until recently support requirements have not been articulated sufficiently in common terms to become established as a fundamental cornerstone in early support system planning. This has not necessarily encouraged but it has permitted re-invention of support requirements in some form or other by each new Computer Resource Working Group (CRWG) as they struggled to develop the Computer Resources Integrated Support Plan (CRISP) and the Operations/Support Configuration Management Procedures (O/SCMP). This lack of recognition of support requirements has also contributed to the practice of "handing down" to the support community all or part of the facilities used during the Full Scale Engineering Development (FSED) phase.

The support concept for the OFP category has followed the same general path as described above for the support requirements and, as might be expected, with approximately the same results. A major contributor to the current problems/issues in the support of OFP's can be traced directly to a lack of firm requirements and support concept. Many of the problems/issues such as funding, organization, documentation, configuration management, and variations in the facilities themselves are the result of a case by case approach to OFP support. There are indications that this approach has worked quite well particularly if the individual AISF's are evaluated also on a case by case basis, but in the aggregate as well as in the future the continued forced fitting of highly technical and mostly technology driven support requirements into a logistics management environment will surely continue to result in less than an optimized command-wide OFP support posture.